Eastern Research Group, Inc.

2017 SUMMER FUEL FIELD STUDY

Final

Prepared for:

Mr. Michael Regan
Texas Commission on Environmental Quality
Air Quality Division
Building F, Room 5168
Austin, TX 78711-3087

August 31, 2017

ERG No. 0345.00.012.006
TCEQ Contract No. 582-15-50416
Work Order No. 582-17-71490-10

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ACRONYMS

AST	aboveground storage tank
ASTM	American Society for Testing and Materials
CAR	corrective action report
CAS	Chemical Abstract Service
DHA	detailed hydrocarbon analysis
E200	lower volatility percentage
E300	upper volatility percentage
EIA	Energy Information Administration
ERG	Eastern Research Group, Inc.
ETBE	Ethyl tert-butyl ether
EtOH	ethanol
IATA	International Air Transport Association
IC	independent contractor
ICAO	International Civil Aviation Association
MOVES	Motor Vehicle Emission Simulator
MTBE	Methyl tert-butyl ether
ppm	parts per million
PPRD	Petroleum Products Research Development
PST	petroleum storage tank
QA/QC	quality assurance/quality control
RVP	Reid Vapor Pressure
SIP	State Implementation Plan
SwRI	Southwest Research Institute
TAME	tert-Amyl methyl ether
TCEQ	Texas Commission on Environmental Quality
TexN	Texas NONROAD model
TxDOT	Texas Department of Transportation
U.S. EPA	U.S. Environmental Protection Agency
ULSD	ultra-low sulfur diesel
UST	underground storage tank
VOC	volatile organic compound

ES.0 EXECUTIVE SUMMARY

Eastern Research Group, Inc. (ERG), along with subcontractor Southwest Research Institute (SwRI), collected summer fuel samples across the State of Texas in the summer of 2017. All gasoline grades (low, mid, and high) and diesel fuel were sampled across 91 gasoline service stations that are located within each of the twenty-five Texas Department of Transportation (TxDOT) districts. The objective of this study was to develop updated Texas-specific fuel parameter files for the U.S. EPA's MOVES and TCEQ's TexN (Texas Nonroad) emissions models.

Testing of various fuel properties was completed in the SwRI laboratory which involved speciation of hydrocarbon compounds including oxygenates, determination of Reid Vapor pressure (RVP), estimation of sulfur content in fuel, and quantification of aromatics, olefins, distillation analysis, and cetane. Additionally, ERG calculated the lower volatility percentage (E200) and the upper volatility percentage (E300) using the results from the distillation tests.

The fuel parameters for gasoline and diesel were averaged for each of the 25 TxDOT districts. For gasoline, ERG calculated weighted averages across the fuel grades using the latest available fuel sales data for Texas. These data were then used to develop updated fuel parameter files for MOVES and TexN.

Additionally, ERG also performed a second round of sampling for the sampling stations located in the Houston district. This second round of sampling and lab analysis was performed to determine temporal variability of fuel properties within the same district and at individual station-level. ERG also compiled district-level fuel parameter data from previous studies and performed a trends analysis for 2003-2017 fuel parameter data, at the district-level.

1.0 INTRODUCTION

Eastern Research Group, Inc. (ERG) was contracted by the Texas Commission on Environmental Quality (TCEQ) to develop updated Texas-specific fuel parameter files for use with MOVES and TexN emission models.

The purpose of this Work Order was to develop physical properties and speciation profiles, and to report laboratory test results for samples of gasoline and diesel fuel collected from retail stations across Texas. Testing of various properties was completed in an approved laboratory (SwRI). The various analytical tests involved speciation of volatile organic compounds (VOC) including oxygenates, determination of RVP and sulfur content in gasoline, and quantification of aromatics, cetane, and sulfur in diesel fuel. Distillation analysis tests were also performed on the collected gasoline and diesel samples.

In order to maintain a high confidence level in the fuel parameters used in the development of on-road and nonroad emission inventories, trend analyses, and control strategy analyses, the TCEQ has undertaken a program to periodically collect and analyze fuel samples. The data will ensure the accuracy of local specific fuel information and provide the best data available to be used for analyses to support Texas State Implementation Plan (SIP) and control strategy development.

Samples of regular unleaded gasoline, mid-grade gasoline, premium-grade gasoline, and Ultra-Low Sulfur Diesel (ULSD) fuel were obtained from 91 retail gas stations. These retail gas stations are located across the 25 different TxDOT districts within the State of Texas.

The following sections of this report summarize the sample collection plan, sample collection and lab analysis steps, data analyses on the collected gasoline and diesel test data and their results, the development of Texas-specific updated fuel parameter files for use in EPA's MOVES and TCEQ's TexN models, temporal analysis comparing round 1 and round 2 results for the Houston TxDOT district, and trend analysis between the 2017 summer data and available data from previous years (2003-2014).

2.0 SAMPLING PLAN

ERG developed a fuel sampling plan to be implemented by SwRI during the summer of 2017 (June/July 2017). ERG used the list of retail stations sampled in the 2014 Summer Fuel Field Study as the master list of retail stations to sample during the current Study (ERG, 2014). These retail stations served as the primary sampling candidates for fuel sampling during the summer of 2017. ERG also developed a list of alternate sampling candidates in case sampling at the primary candidate location was not possible.

2.1 Fuel Sampling Plan and Site Selection

ERG developed a sampling plan that specified the number of stations per TxDOT district (district), the total number of samples (including number of diesel and gas samples, across gas grades), and the allocation of stations across the districts. The sampling plan specifications included the following:

- Each fuel sampling district has a minimum of three sample sites;
- Both diesel and gasoline samples are to be collected at each location;
- Regular, mid-grade, and premium gasoline grades are to be sampled; and
- Gasoline and diesel samples are to be collected separately (no compositing).

This approach required a lab test of every sample. As a result, it was more expensive and limited the total number of stations that could be sampled. However, it did provide an indication of differences within areas that would not be discernable using a compositing approach. Specifically, this approach enabled the determination of minimum, maximum, and average fuel parameter values, instead of just averages for each region. This characterization is more consistent with MOVES modeling, in that it will allow the TCEQ to specify maximum and average parameter values for model inputs, such as fuel sulfur levels.

Table 1 summarizes the number of stations that were initially sampled for each district. At each station, three gasoline samples and one diesel sample were obtained.

Table 1. Initial Sampling Plan Summary Table

TxDOT District	Number of Stations	Area Designation
Abilene	3	Attainment Area
Amarillo	3	Attainment Area
Atlanta	3	Attainment Area
Austin	5	Attainment Area (Former Early Action Compact Area)
Beaumont	5	Beaumont-Port Arthur Nonattainment Area
Brownwood	3	Attainment Area
Bryan	3	Attainment Area
Childress	3	Attainment Area
Corpus Christi	3	Attainment Area
Dallas	4	Dallas-Ft. Worth Nonattainment Area
El Paso	5	Attainment Area (Maintenance)
Fort Worth	4	Dallas-Ft. Worth Nonattainment Area
Houston	7*	Houston-Galveston-Brazoria Nonattainment Area
Laredo	3	Attainment Area
Lubbock	3	Attainment Area
Lufkin	3	Attainment Area
Odessa	3	Attainment Area
Paris	3	Attainment Area
Pharr	3	Attainment Area
San Angelo	3	Attainment Area
San Antonio	5	Attainment Area (Former Early Action Compact Area)
Tyler	5	Attainment Area (Former Early Action Compact Area)
Waco	3	Attainment Area
Wichita Falls	3	Attainment Area
Yoakum	3	Attainment Area
Total	**91**	

* These stations were sampled a second time later in the summer, as described below.

The retail stations that were sampled were all "active" retail establishments. The master sampling list did not include non-retail establishments such as, bulk fuel terminals, state agency fleet refueling stations, and municipal and private fleet refueling stations, and automobile dealers. All 91 retail stations in the master list were identified as selling both gasoline and diesel fuel. Also, the master list facilities had tank capacities greater than or equal to 10,000 gallons. The master list of sampling stations was obtained from the master sampling list developed during the 2014 summer fuel field study.

Apart from the master list of sampling stations, ERG also developed a list of alternate sampling stations. The alternate sampling stations were to be used in the event that sampling at any primary sampling station was not possible (i.e., out of business, temporarily closed, did not sell 3 grades of gasoline, or otherwise inaccessible). As indicated in the initial sampling plan presented in Table 1, three to seven primary sampling candidates were selected for each district. In addition, another six to fourteen alternate sampling candidates (two times the number of primary sampling candidates) were also selected for each district, within the same city if possible. ERG used data from the TCEQ to develop the list of alternate sampling candidates.

The latest Petroleum Storage Tank (PST) data were obtained from TCEQ staff via email (Regan 2017). The PST datasets contained the following information on facilities with underground storage tanks (USTs) and/or aboveground storage tanks (ASTs):

- Facility information (facility status [active or inactive], facility type [retail, aircraft, fleet, etc.], location, number of tanks, and enforcement action);
- Tank information (tank size and status [in-use, removed, etc.]); and
- Composition information (tank-specific information including fuel type).

Data from these datasets (USTs and ASTs) were merged into one master file for alternative site selection purposes. Next, only retail establishments were selected where the status was "active" within the PST database. The next step was to include only stations that sell both gasoline and diesel. Also, to ensure that the larger service stations will be sampled – tank size being used as a surrogate for fuel throughput, since actual throughput data is only available at the wholesale level – the list was narrowed down by extracting only those facilities that had tank capacities greater than or equal to 10,000 gallons. Furthermore, ERG filtered out the stations with enforcement actions against them from the TCEQ. Each of the retail stations remaining on the list was then assigned to the appropriate district based on county designation.

From this merged list, ERG selected six to fourteen alternative sampling stations for each district with the goal to select two times as many alternative sampling stations in case sampling at the primary station(s) was not possible. In most cases, alternate sampling locations were selected such that they were located within the same city as the primary sampling locations. Also, ERG selected retail stations with the most number of tanks as the alternate sampling candidates.

In an additional step, ERG checked the latest TCEQ PST data to verify if the primary candidates (selected from the 2014 study) were still active. Out of the total 91 primary sampling candidates, 22 stations were not listed by the same name in the latest TCEQ PST data. Of these 22, ERG matched 15 stations based on their physical address. These 15 stations were present in the latest TCEQ data, but with a different name (potentially due to change of ownership). ERG was not able to match the remaining 7 stations by name or by physical address (potentially due to temporary or permanent shut down, TCEQ enforcement action, or tank status is not in use). For these 7 sampling sites, ERG selected sampling locations from the alternate sampling list within the same city/TxDOT district.

2.2 Initial Sampling

During the initial sampling conducted in June 2017, sampling was not possible at fifteen (15) retail gas stations out of the 91 master sampling sites. For these 15 sites, sampling was conducted at the closest alternate sampling site. The reasons for sampling not being possible at these 15 sampling sites are as follows:

- Eight sampling sites did not carry all 3 grades of gasoline,
- Three sampling sites were permanently closed,
- One sampling site address was erroneous (doctor's office at given address),
- One sampling site's owner/operator refused the sampling team, and
- Two sampling sites had changed ownership and switched fuel brands (sampling was conducted at these sites, but under new name).

During the initial round (round 1) of sampling, a total of 273 gasoline samples (91 stations and 3 gasoline grades sampled at each station) and 91 diesel fuel samples (1 diesel fuel sample per sampling location) were collected across the 25 TxDOT districts. The list of final sampling locations is presented in Attachment 1.

2.3 Second Round of Sampling

In addition to the initial round of sampling, a second round of testing was conducted in an attempt to obtain a better understanding of temporal variability of fuel composition within a district. For a small subset of fueling stations (the seven sampling sites located in the Houston district), SwRI conducted a second round of sampling, ensuring that enough time elapsed for complete tank turnover (4 weeks). This second round of sampling was intended to make a preliminary assessment of the temporal variability of fuel parameters at the station level.

3.0 SAMPLING AND LABORATORY ANALYSIS

This section describes the sampling protocol and laboratory tests performed for this study. For this task, SwRI provided sample containers and packaging, gasoline and diesel sample acquisition services from retail stations, sample shipping, sample handling, and sample testing for summer fuels in 2017.

3.1 Retail Station and Sample Collection and Handling Procedures

Independent contractors (ICs) working with SwRI acquired the fuel samples from retail stations. Each IC received written instructions, master and alternate sampling lists, service station sampling procedures, sample containers, shipping instructions, etc. from SwRI. All contractors were instructed on retail station sampling procedures with special emphasis on sample handling, and safe disposal of flushed fuel.

SwRI used U.S. Department of Transportation (DOT) and International Air Transport Association (IATA) approved fuel sample containers and shipping cartons. The shipping boxes were assembled at SwRI by trained staff, and all appropriate shipping materials were provided to the ICs along with FedEx-approved instructions for shipment of hazardous materials/dangerous goods. The containers were delivered cleaned and dried to the ICs.

For gasoline samples, the ICs purged three gallons of gasoline product through the pump nozzle before obtaining a sample, or purged ½ gallon of the appropriate fuel immediately after the appropriate grade was purchased by the previous customer. When possible the temperature of the flushed sample was recorded. Immediately after the fuel was flushed from the pump, the ICs attached a spacer, when needed, to the pump nozzle. The nozzle extension was inserted into the sample container. The pump nozzle was inserted into the extension with slot over the air bleed hole. The sample container was slowly filled through the nozzle extension to 70 to 85% full. The nozzle extension was removed and the sample container was capped and sealed. Checks were also performed for leaks. The sample were then prepared for air shipment. Additionally, the ICs also recorded the type of fuel pump pad material (e.g., concrete, asphalt) at each sampling station.

In case of diesel samples, the ICs filled the sample container slowly to 70 to 85% full. The container was then capped and sealed. The sealed sample container was then checked for leaks and prepared for air shipment. The ICs also recorded the sulfur content label information at the diesel pump used to obtain the diesel sample.

The ICs used FedEx air shipments for sample shipment return to SwRI. Members of the SwRI shipping and receiving team meet regularly with FedEx and attend IATA and International Civil Aviation Association (ICAO) hazardous materials shipping and handling training sessions to keep abreast of current regulations. All samples were chilled.

3.2 Laboratory Testing

All testing was accomplished in the PPRD laboratories of the Automotive Products and Emissions Research Division at Southwest Research Institute. The facilities are located at 6220 Culebra Road, San Antonio, Texas.

3.2.1 Gasoline Testing

Gasoline testing was performed on individual regular, mid-grade, and premium gasoline samples. There was no compositing of samples, as discussed above. Key testing methods included:

- Reid vapor pressure (ASTM D5191-15)
- Sulfur (ASTM D2622-16)
- Distillation (ASTM D86-16a)
- Benzene (ASTM D3606-10e1)
- Total aromatics and olefins (ASTM D1319-15)
- Oxygenates (ASTM D5599-15)
- Detailed Hydrocarbon Analysis (ASTM D6729-14)

Gasoline sample test results for all 273 gasoline samples collected in the initial round are provided in Attachment 2. These do not include the round 2 sampling conducted for the seven sampling locations in Houston district.

3.2.2 Diesel Testing

Diesel samples were acquired from all 91 sampling locations. Sample testing performed on each diesel sample included:

- Cetane Number (ASTM D613-16a)
- Calculated cetane index (ASTM D976-06(2016))
- API Gravity (ASTM D287-12b)
- Specific Gravity (ASTM D1298-12b)
- Sulfur (ASTM D5453-16e1)
- Nitrogen (ASTM D4629-12)
- Aromaticity (ASTM D1319-15)
- Total aromatic content (ASTM D5186-15)
- Polycyclic aromatic content (ASTM D5186-15)
- Distillation (ASTM D86-16a)
- Flash point (ASTM D93-16a)

Sample identification information and test results for all the diesel samples collected in the initial sampling round are provided in Attachment 3. These do not include the round 2 sampling conducted for the seven sampling locations in Houston district.

4.0 DEVELOPING UPDATED FUEL PARAMETERS FOR TEXAS

ERG used gasoline and diesel fuel sample analysis data collected by SwRI to develop fuel parameter input data for EPA's MOVES model (MOVES2014a) and TCEQ's Texas NONROAD model (TexN). Fuel parameter data were developed for each county in Texas using the fuel sample analysis data.

4.1 Gasoline Analysis

The SwRI gasoline data required significant formatting prior to development of the average fuel parameter values. The gasoline data were transmitted to ERG in two separate datasets – the "DHA" dataset for the detailed hydrocarbon analysis results, and the "OTH" dataset for all other test results for gasoline samples. The DHA data was compiled in a single worksheet with each sample containing header, group summary, group component data, and group carbon data. The header section of the DHA data contained service station information, sample information, and date sample was collected. The group summary section contained composition information (i.e., % volume, % weight, and % mol) for various hydrocarbon groups (e.g., paraffins, aromatics, olefins, oxygenates, etc.). The group component section contained composition information for the various sub-components (i.e., ETBE, MTBE, TAME, Ethanol, propane, i-butane, etc.) of the groups listed under the group summary section. This section also includes the Chemical Abstracts Service (CAS) number for each of the sub-components. ERG proceeded to extract only the required parameters into one large flat file.

Historically, data from the detailed hydrocarbon analysis (DHA) were used to report data for specific contaminants from each sample (e.g., benzene, ETBE, MTBE, TAME, EtOH, aromatics, and olefins). However, beginning in 2011, data for these parameters were also reported using the ASTM D5599 test, while aromatics and olefins were determined using the ASTM D1319 test method. For this study, ERG used the data results obtained from the OTH analysis using the ASTM D5599 and ASTM D1319 test methods to develop the required fuel parameters for MOVES and TexN. The OTH dataset was already in a flat file format and further processing was not required. Test results for the following fuel parameters were obtained from the OTH dataset for each gasoline sample for further analysis:

- RVP

- Sulfur
- Aromatics
- Olefins
- Benzene
- Ethanol
- ETBE
- MTBE
- TAME
- Distillation results for 50% and 90% of sample fraction (Evap_50 and Evap_90)

Using the distillation results for 50% and 90% sample fractions, ERG calculated the lower volatility percentage (E200) and upper volatility percentage (E300).

Since three grades of gasoline were sampled, regular, mid-grade, and premium grade data were extracted separately. Required fuel parameters (e.g., RVP, fuel sulfur, benzene, ethanol, MTBE, ETBE, and TAME) were then averaged by district and by gasoline grade. For example, benzene was averaged for each of the 25 districts, for regular, mid-grade, and premium grades individually.

ERG then calculated a weighted-average across all three gasoline grades for each district based on the latest refiner motor gasoline sales data obtained from the Energy Information Administration (EIA). According to the EIA data for Texas in 2015 (latest available annual data), regular gasoline comprised 87.1% of the market, mid-grade gasoline comprised 5.7%, and premium gasoline comprised 7.2% (EIA, 2017).

4.2 Diesel Analysis

The SwRI diesel analysis data was in a flat file format, very similar to the OTH file for gasoline data as described in section 4.1 above. The diesel data contained information on the service station where the sample was collected, fuel composition data, and distillation data. The diesel fuel analysis focused on the following fuel parameters:

- Specific gravity,

- Aromatics,
- Olefins,
- Saturates,
- Sulfur content,
- Cetane number, and
- Distillation data (Evap_50)

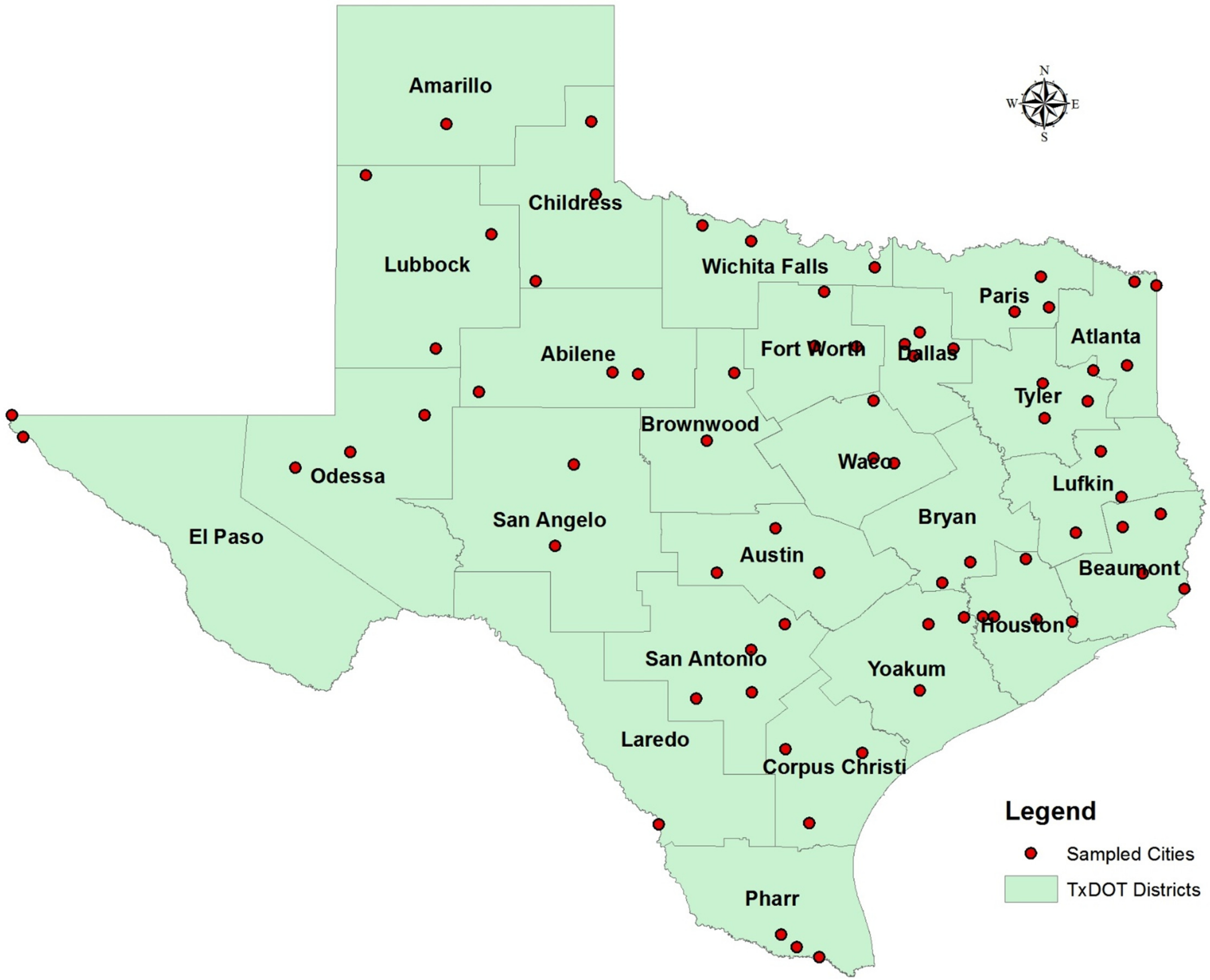
The diesel fuel test data were grouped by district and unweighted average fuel parameters were calculated for each district.

4.3 Updated Fuel Parameter Files

Once the fuel parameter averages were calculated at the district-level for gasoline samples and for diesel samples, ERG then developed county-level fuel parameter averages for gasoline and diesel fuel. ERG used the TxDOT district-to-county mapping and assigned district-level fuel parameter average values to each county that was located within the same district. The district to county assignments were identical to those developed for the 2014 summer fuel field study. Since the TxDOT district-to-county assignments did not change since the 2014 study was conducted, no adjusted allocation scheme was necessary for the 2014 data to account for differences between the sampling region boundaries and TxDOT districts.

Figure 1 indicates the TxDOT District boundaries and sampling city locations.

Figure 1. TxDOT Districts and Sampling Areas



The fuel parameter data for the 2017 summer sampling results were compiled, processed, and formatted for use as an input file for the MOVES2014a model. ERG first used the County Data Manager module in the MOVES2014a model and exported the fuel data template as an Excel file. Next, ERG updated the Fuel Formulation and the Fuel Supply tables in the fuel template with the 2017 summer fuel sampling data. All other tables related to fuel data were left as defaults.

This process resulted in populating an Excel spreadsheet containing the 2017 summer fuel data collected for the TCEQ. This file may be edited according to user needs and imported directly into MOVES using the County Data Manager within MOVES2014a.

Similarly, the fuel data template was exported from the TexN model in spreadsheet format and was updated with the applicable 2017 summer fuel sampling data. The spreadsheets containing data to update the fuel parameter inputs for MOVES and TexN are provided in Attachment 4a. The spreadsheet also contains MySQL scripts that are needed to update and load the updated fuel parameter data into TexN.

4.4 Findings

The average values for selected fuel parameters for gasoline are presented in Table 2 at the district level. Similarly, average values for selected fuel parameters for diesel fuel are presented in Table 3.

Selected fuel parameters from the initial round gasoline DHA and OTH datasets in flat-file format, district-level averages by gasoline grade, district-level weighted-averages across all grades, and county-level averages are provided in Attachment 4b. Similarly, diesel fuel test results, district-level averages, and county-level averages for diesel fuel are also provided in Attachment 4b.

Table 2. Gasoline Fuel Properties by District (Summer 2017)

Region	RVP	Sulfur (ppm)	Aromatics (% wt)	Olefins (% wt)	Benzene (% wt)	EtOH (% vol)	MTBE (% vol)	ETBE (% vol)	TAME (% vol)	E200 (%)	E300 (%)
Abilene	9.88	14.8	27.42	10.09	0.6	10	0	0	0	53.96	86.33
Amarillo	9.75	9.2	24.29	3.67	0.66	9.96	0	0	0	55.28	87.27
Atlanta	7.61	21.4	29.61	6.41	1.12	9.57	0.0009	0	0	48.43	83.04
Austin	7.63	30	22.41	14.76	0.35	9.68	0	0	0	48.34	78.61
Beaumont	7.6	20.7	27.9	5.08	1.08	9.76	0.0012	0	0	50.51	84.38
Brownwood	8.75	19.6	25.43	9.91	0.81	9.34	0	0	0	51.46	84.55
Bryan	7.64	17	29.37	3.66	1	9.72	0.0002	0	0	50.75	82.88
Childress	9.69	11.3	26.57	4.11	0.72	9.94	0	0	0	55.35	87.26
Corpus Christi	7.56	17.8	17.62	14.91	0.58	9.35	0	0	0	52.73	84.58
Dallas	7.25	20.8	18.09	9.41	0.64	9.6	0	0	0	50.37	85.87
El Paso	6.94	19.6	26.69	5.48	1.13	9.6	0	0	0	48.72	87.83
Fort Worth	7.24	19.2	18.53	9.47	0.58	9.63	0	0	0	51.28	85.45
Houston	7.08	18.4	19.37	10.45	0.58	9.66	0	0	0	49.23	83.95
Laredo	8.04	25.2	24.85	10.72	0.36	9.64	0	0	0	51.74	81.58
Lubbock	9.78	15	22.88	6.48	0.67	9.96	0	0	0	54.79	86.35
Lufkin	7.66	14.3	27.18	2.62	0.87	9.74	0.001	0	0	48.65	84.4
Odessa	9.78	19.2	24.85	11.4	0.67	9.93	0	0	0	55.01	86.38
Paris	7.52	20.6	26.35	8.7	1.02	9.64	0	0	0	48.96	83.82
Pharr	9.57	19.3	15.35	14.09	0.63	9.53	0	0	0	54.5	85.67
San Angelo	9.11	24.9	20.35	9.46	0.6	9.21	0	0	0	53.04	84.16
San Antonio	7.48	28.8	26.86	9.32	0.33	9.67	0	0	0	48.55	80.33
Tyler	7.5	17.2	28.28	5.57	1	9.64	0	0	0	47.41	84.03
Waco	7.68	28.3	25.01	12.28	0.49	9.58	0	0	0	49.37	78.97
Wichita Falls	9.11	29	26.34	9.5	0.68	9.75	0	0	0	52.51	85.72
Yoakum	7.59	14.6	24.7	6.05	0.75	9.72	0	0	0	50	82.94
Average	***8.22***	***19.85***	***24.25***	***8.54***	***0.72***	***9.67***	***0.00014***	***0***	***0***	***51.24***	***84.25***
Min	***6.94***	***9.2***	***15.35***	***2.62***	***0.33***	***9.21***	***0***	***0***	***0***	***47.41***	***78.61***

Table 2. Gasoline Fuel Properties by District (Summer 2017)

Region	RVP	Sulfur (ppm)	Aromatics (% wt)	Olefins (% wt)	Benzene (% wt)	EtOH (% vol)	MTBE (% vol)	ETBE (% vol)	TAME (% vol)	E200 (%)	E300 (%)
Max	***9.88***	***30***	***29.61***	***14.91***	***1.13***	***10***	***0.0012***	***0***	***0***	***55.35***	***87.83***
Range	***2.94***	***20.8***	***14.26***	***12.29***	***0.8***	***0.79***	***0.0012***	***0***	***0***	***7.94***	***9.22***
Standard Deviation	***1.023***	***5.45***	***3.93***	***3.51***	***0.23***	***0.19***	***0.00036***	***0***	***0***	***2.52***	***2.42***

Table 3. Diesel Fuel Properties by Region (Summer 2017)

Region	Aromatics, % wt	Olefins, % wt	Saturate, % wt	Sulfur, ppm	Cetane No.	Specific Gravity	T50, deg F
Abilene	25.22	1.65	73.13	10.09	48.73	0.85	517.37
Amarillo	22.02	1.39	76.59	6.29	49.57	0.84	498.80
Atlanta	22.93	1.75	75.32	7.54	49.67	0.84	515.47
Austin	18.81	1.04	80.15	7.30	53.46	0.83	516.04
Beaumont	32.15	1.12	66.73	6.32	45.78	0.85	517.28
Brownwood	27.19	1.91	70.90	7.94	48.27	0.85	520.13
Bryan	28.50	1.71	69.79	6.21	48.50	0.85	514.77
Childress	19.65	1.03	79.32	6.14	50.00	0.83	492.37
Corpus Christi	21.22	1.13	77.65	5.91	50.40	0.84	534.77
Dallas	24.56	1.68	73.76	6.09	48.50	0.85	518.38
El Paso	22.00	1.41	76.59	4.05	50.26	0.84	511.40
Fort Worth	20.96	1.37	77.68	6.42	51.05	0.84	501.83
Houston	23.20	1.23	75.56	5.41	50.33	0.85	534.73
Laredo	12.34	1.04	86.62	4.81	57.13	0.82	486.37
Lubbock	20.60	1.36	78.04	5.95	50.00	0.84	492.93
Lufkin	32.94	1.40	65.66	6.11	45.13	0.85	504.23
Odessa	25.22	1.52	73.26	7.21	49.40	0.85	520.77
Paris	15.18	1.47	83.35	9.04	52.93	0.84	522.93
Pharr	16.09	1.23	82.68	3.82	54.43	0.83	514.37
San Angelo	24.82	1.32	73.86	6.75	48.03	0.84	505.07
San Antonio	21.21	1.25	77.54	5.45	51.26	0.83	499.48
Tyler	19.77	1.71	78.52	7.65	49.60	0.84	520.08
Waco	22.89	0.83	76.28	7.60	53.33	0.83	511.67
Wichita Falls	22.13	1.46	76.41	5.86	49.77	0.84	522.03
Yoakum	24.42	1.45	74.13	5.47	50.37	0.84	516.00
Average	***22.64***	***1.38***	***75.98***	***6.46***	***50.24***	***0.84***	***512.37***
Min	***12.34***	***0.83***	***65.66***	***3.82***	***45.13***	***0.82***	***486.37***
Max	***32.94***	***1.91***	***86.62***	***10.09***	***57.13***	***0.85***	***534.77***
Range	***20.60***	***1.08***	***20.96***	***6.27***	***12.00***	***0.03***	***48.40***
Standard Deviation	***4.68***	***0.27***	***4.77***	***1.40***	***2.58***	***0.008***	***12.19***

5.0 TEMPORAL VARIABILITY AND TREND ANALYSIS

In addition to the initial round of sampling, a second round of sampling and lab analysis was conducted for a subset of sampling stations (the seven located in the Houston district). The data from the second round of sampling were intended to assess the temporal variation of fuel parameters within a single district. The temporal variability analyses for the Houston district are described in this section. This section also describes the trend analyses performed by ERG using available fuel parameter data from previous years (2003 – 2014) and the results from the sampling conducted in summer 2017.

5.1 Temporal Variability (Round 1 Vs. Round 2 data)

For the Houston district, ERG sampled gasoline and diesel fuel from 7 retail gasoline stations during the first week of June 2017. A second round of sampling was conducted for the same 7 retail stations during the first week of July 2017. The purpose of the second round of sampling was to determine temporal variation in fuel composition within the same district and also to assess temporal variability of fuel within the same retail station. The 2nd round of sampling was conducted 4 weeks after completion of the initial sampling. The 4 weeks wait period between both the sampling events was to ensure complete tank turnover at all 7 Houston district sampling locations.

Table 4 presents the list of sampling stations for the Houston district where 1st and 2nd round of sampling were conducted during the summer of 2017.

Table 4. Houston District Sampling Stations

Station ID	Station Name
1	Flying J Travel Plaza 729
2	Loves Travel Stop 401
3	Baytown Express Travel Center
4	Flying J Travel Plaza 740
5	Loves Travel Stop 315
6	Loves Travel Stop 234
7	Loves Travel Stop 468

The 2nd round of sampling test results were identical in format to the initial round of sampling results data received from SwRI. The processing steps performed on the 2nd round of sampling test results are the same as the ones performed on the initial sampling data, as described in section 4 of this report. Tables 5 and 6 present the results of the second round of sampling compared to the first round of sampling for the seven stations in the Houston district. Table 5 presents the results of gasoline sampling data and Table 6 presents diesel fuel sampling results.

Table 5. Station-Specific Gasoline Fuel Results, Round 1 vs. Round 2

Station ID	Fuel Component	Round 1 Results	Round 2 Results	Difference (R2 – R1)	% Difference
1	RVP, psi	6.89	6.9	0.01	0.15%
	Benzene, % Volume	0.41	0.38	-0.03	-7.32%
	ETOH, % Volume	9.81	9.89	0.08	0.82%
	MTBE, % Volume	0	0	0	0.00%
	ETBE, % Volume	0	0	0	0.00%
	TAME, % Volume	0	0	0	0.00%
	Aromatics, % Volume	21.16	20.39	-0.77	-3.64%
	Olefins, % Volume	10.58	9.98	-0.6	-5.67%
	Sulfur, ppm	8.6	7.73	-0.87	-10.12%
	E200	51.18	49.72	-1.46	-2.85%
	E300	83.2	82.94	-0.26	-0.31%
2	RVP, psi	7.2	7.23	0.03	0.42%
	Benzene, % Volume	0.63	0.53	-0.1	-15.87%
	ETOH, % Volume	9.7	9.52	-0.18	-1.86%
	MTBE, % Volume	0	0	0	0.00%
	ETBE, % Volume	0	0	0	0.00%
	TAME, % Volume	0	0	0	0.00%
	Aromatics, % Volume	19.23	17.04	-2.19	-11.39%
	Olefins, % Volume	9.97	10.86	0.89	8.93%
	Sulfur, ppm	22.8	25.38	2.58	11.32%
	E200	49.4	49.27	-0.13	-0.26%
	E300	85.25	85.08	-0.17	-0.20%
3	RVP, psi	7.02	7.19	0.17	2.42%
	Benzene, % Volume	0.41	0.42	0.01	2.44%
	ETOH, % Volume	9.64	9.54	-0.1	-1.04%
	MTBE, % Volume	0	0	0	0.00%
	ETBE, % Volume	0	0	0	0.00%
	TAME, % Volume	0	0	0	0.00%
	Aromatics, % Volume	19.35	17.22	-2.13	-11.01%
	Olefins, % Volume	10.45	12.71	2.26	21.63%
	Sulfur, ppm	8.93	14.53	5.6	62.71%
	E200	49.66	49.13	-0.53	-1.07%
	E300	83.07	83.63	0.56	0.67%
4	RVP, psi	7.09	7.08	-0.01	-0.14%
	Benzene, % Volume	0.71	0.48	-0.23	-32.39%
	ETOH, % Volume	9.27	9.61	0.34	3.67%
	MTBE, % Volume	0	0	0	0.00%
	ETBE, % Volume	0	0	0	0.00%

Table 5. Station-Specific Gasoline Fuel Results, Round 1 vs. Round 2

Station ID	Fuel Component	Round 1 Results	Round 2 Results	Difference (R2 – R1)	% Difference
	TAME, % Volume	0	0	0	0.00%
	Aromatics, % Volume	18.43	18.05	-0.38	-2.06%
	Olefins, % Volume	12.17	11.6	-0.57	-4.68%
	Sulfur, ppm	17.45	22.18	4.73	27.11%
	E200	49.15	48.69	-0.46	-0.94%
	E300	83.27	84.37	1.1	1.32%
5	RVP, psi	7.13	7.1	-0.03	-0.42%
	Benzene, % Volume	0.67	0.51	-0.16	-23.88%
	ETOH, % Volume	9.66	10.02	0.36	3.73%
	MTBE, % Volume	0	0	0	0.00%
	ETBE, % Volume	0	0	0	0.00%
	TAME, % Volume	0	0	0	0.00%
	Aromatics, % Volume	18.65	17.86	-0.79	-4.24%
	Olefins, % Volume	9.74	10.95	1.21	12.42%
	Sulfur, ppm	23.11	26.04	2.93	12.68%
	E200	48.76	48.92	0.16	0.33%
	E300	84.85	85.29	0.44	0.52%
6	RVP, psi	7.1	7.19	0.09	1.27%
	Benzene, % Volume	0.59	0.66	0.07	11.86%
	ETOH, % Volume	9.93	10.04	0.11	1.11%
	MTBE, % Volume	0	0	0	0.00%
	ETBE, % Volume	0	0	0	0.00%
	TAME, % Volume	0	0	0	0.00%
	Aromatics, % Volume	19.06	16.94	-2.12	-11.12%
	Olefins, % Volume	9.37	11.61	2.24	23.91%
	Sulfur, ppm	25.24	25.61	0.37	1.47%
	E200	47.84	49.25	1.41	2.95%
	E300	84.04	85.72	1.68	2.00%
7	RVP, psi	7.11	7.11	0	0.00%
	Benzene, % Volume	0.68	0.59	-0.09	-13.24%
	ETOH, % Volume	9.59	9.78	0.19	1.98%
	MTBE, % Volume	0	0	0	0.00%
	ETBE, % Volume	0	0	0	0.00%
	TAME, % Volume	0	0	0	0.00%
	Aromatics, % Volume	19.68	17.47	-2.21	-11.23%
	Olefins, % Volume	10.83	11.55	0.72	6.65%
	Sulfur, ppm	22.66	25.73	3.07	13.55%
	E200	48.64	49.5	0.86	1.77%
	E300	84	86.1	2.1	2.50%

As can be seen from Table 5 above, there are substantial relative variations between the Houston district stations for gasoline samples collected in round 1 compared to those collected in round 2. The largest decrease between the round 1 and round 2 results is for benzene and aromatics, and the largest increase is for sulfur level and olefin values. The highest increase overall is for station ID 3. The sulfur value of gasoline samples collected at station 3 increase by approximately 63% for round 2 compared with round 1 results.

Table 6. Station-Specific Diesel Fuel Results, Round 1 vs. Round 2

Station ID	Fuel Component	Round 1 Results	Round 2 Results	Difference (R2 – R1)	% Difference
1	Specific Gravity	0.857	0.863	0.01	0.67%
	Aromatics, % Volume	26.7	26.4	-0.30	-1.12%
	Olefins, % Volume	1.1	1	-0.10	-9.09%
	Saturates, % Volume	72.2	72.6	0.40	0.55%
	Sulfur, ppm	5.23	5.76	0.53	10.13%
	Cetane Number	53.6	48.4	-5.20	-9.70%
	T50, deg F	543.4	548.3	4.90	0.90%
2	Specific Gravity	0.85	0.84	-0.004	-0.48%
	Aromatics, % Volume	19.4	16.8	-2.60	-13.40%
	Olefins, % Volume	1.2	1.5	0.30	25.00%
	Saturates, % Volume	79.4	81.7	2.30	2.90%
	Sulfur, ppm	5.65	5.37	-0.28	-4.96%
	Cetane Number	47.1	49.4	2.30	4.88%
	T50, deg F	533.3	531.8	-1.50	-0.28%
3	Specific Gravity	0.84	0.85	0.01	1.12%
	Aromatics, % Volume	21.8	27.9	6.10	27.98%
	Olefins, % Volume	1	2.7	1.70	170.00%
	Saturates, % Volume	77.2	69.4	-7.80	-10.10%
	Sulfur, ppm	6.18	7.14	0.96	15.53%
	Cetane Number	49.5	46.9	-2.60	-5.25%
	T50, deg F	519.4	535.4	16.00	3.08%
4	Specific Gravity	0.858	0.863	0.005	0.56%
	Aromatics, % Volume	26.4	30.9	4.50	17.05%
	Olefins, % Volume	2	2.4	0.40	20.00%
	Saturates, % Volume	71.6	66.7	-4.90	-6.84%
	Sulfur, ppm	5.7	6.06	0.36	6.32%
	Cetane Number	53.8	48.6	-5.20	-9.67%
	T50, deg F	544.6	547.7	3.10	0.57%
5	Specific Gravity	0.85	0.84	-0.01	-0.59%
	Aromatics, % Volume	20.7	20.8	0.10	0.48%
	Olefins, % Volume	0.9	1.6	0.70	77.78%
	Saturates, % Volume	78.4	77.6	-0.80	-1.02%
	Sulfur, ppm	4.97	5.75	0.78	15.69%
	Cetane Number	48.9	48	-0.90	-1.84%
	T50, deg F	535.2	518.7	-16.50	-3.08%
6	Specific Gravity	0.85	0.84	-0.04	-0.41%
	Aromatics, % Volume	22.5	20.6	-1.90	-8.44%
	Olefins, % Volume	1.4	2	0.60	42.86%
	Saturates, % Volume	76.1	77.4	1.30	1.71%
	Sulfur, ppm	5.07	5.61	0.54	10.65%

Table 6. Station-Specific Diesel Fuel Results, Round 1 vs. Round 2

Station ID	Fuel Component	Round 1 Results	Round 2 Results	Difference (R2 – R1)	% Difference
	Cetane Number	48	48.5	0.50	1.04%
	T50, deg F	532.5	525.2	-7.30	-1.37%
7	Specific Gravity	0.846	0.842	-0.004	-0.48%
	Aromatics, % Volume	20.6	20.3	-0.30	-1.46%
	Olefins, % Volume	1.1	2.4	1.30	118.18%
	Saturates, % Volume	78.3	77.3	-1.00	-1.28%
	Sulfur, ppm	5.08	5.69	0.61	12.01%
	Cetane Number	51.4	48.8	-2.60	-5.06%
	T50, deg F	534.7	522.5	-12.20	-2.28%

Round 1 and round 2 diesel fuel sampling results indicate significant variation for diesel fuel olefin values. The olefin values exhibit a general upwards trend (i.e., increase in value from round 1 to round 2) for all stations, except station ID 1. Station ID 1 indicates a modest decrease in olefin values of approximately 9%. For the remaining stations (IDs 2 thru 7), olefins exhibit an increase in the round 2 values as compared to round 1 values, with station IDs 3 and 7 indicating the highest increase of 170% and 118% respectively. The percent increase for the olefin values is high as the absolute olefin numbers are quite small. The increase of 170% corresponds to olefin content values for station ID 3 increasing from 1.0 to 2.7. These olefin values are within the range of olefin values observed in the diesel round 1 analysis data provided by SwRI. Sulfur content values also exhibit a general increase for all the stations except station ID 2. Station ID 2 indicates a slight decrease in sulfur content of approximately 5%, whereas the remaining stations indicate a modest increase in values ranging from 6% to 16%.

All the gasoline and diesel analysis data from round 1 and round 2 for the Houston district are available in Attachment 5a. Attachment 5a includes the round 1 and round 2 raw sampling results received from SwRI for diesel and gasoline samples. It also contains the data presented in Tables 5 and 6, and Houston district-level averages for selected fuel parameters for round 1 and round 2 sampling of gasoline and diesel fuel.

5.2 Trends Analysis

ERG performed a trends analysis comparing the sampling results for gasoline and diesel fuel collected during the summer of 2017 with those collected for the summers of 2003 through 2014. Data in the 2003-2014 period are not available for all years. Note that no testing was conducted in the summers of 2006, 2009, 2010, 2012, 2013, 2015, and 2016. For gasoline fuel, aromatics, olefins, and benzene values are presented on a percent volume basis, as percent weights were not available for all the historical years. Similarly, for diesel fuel, aromatics and olefin values are presented on a percent volume basis.

Figures 2 through 13 illustrate the trends in selected gasoline fuel parameters for selected district from 2003 through 2017. Figures 14 through 21 illustrate the diesel fuel composition trends from 2003 through 2017 for selected diesel fuel parameters. All the trends analysis data is available in Attachment 5b.

Figure 2. Gasoline RVP Trends for Selected Districts

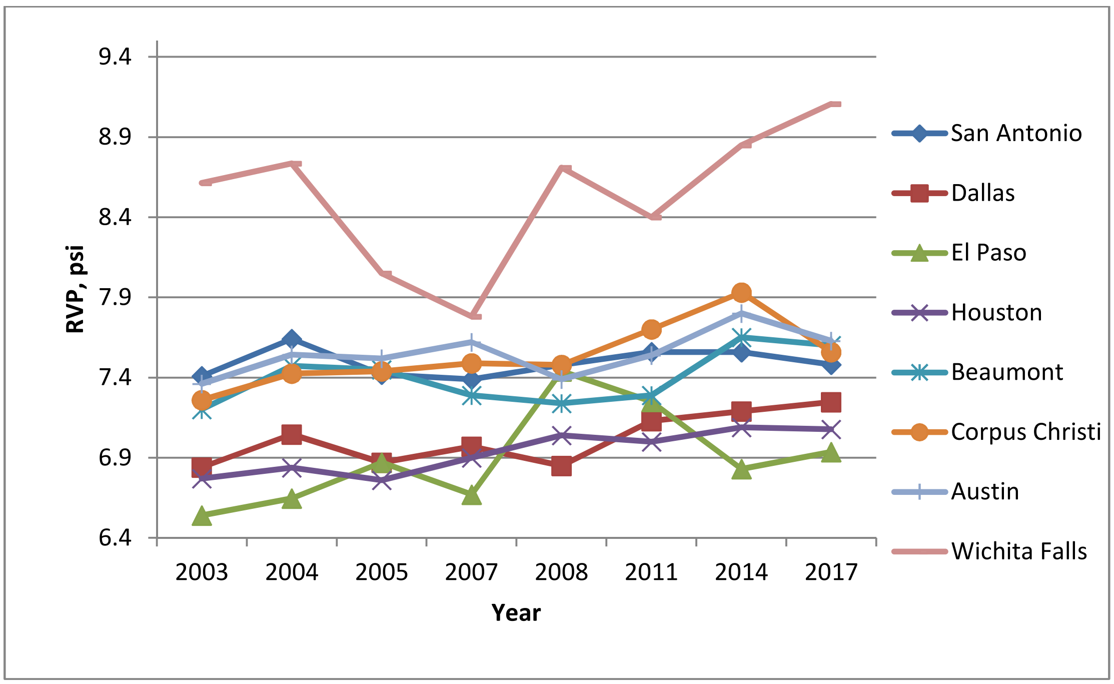


Figure 3. Gasoline Sulfur Trends for Selected Districts

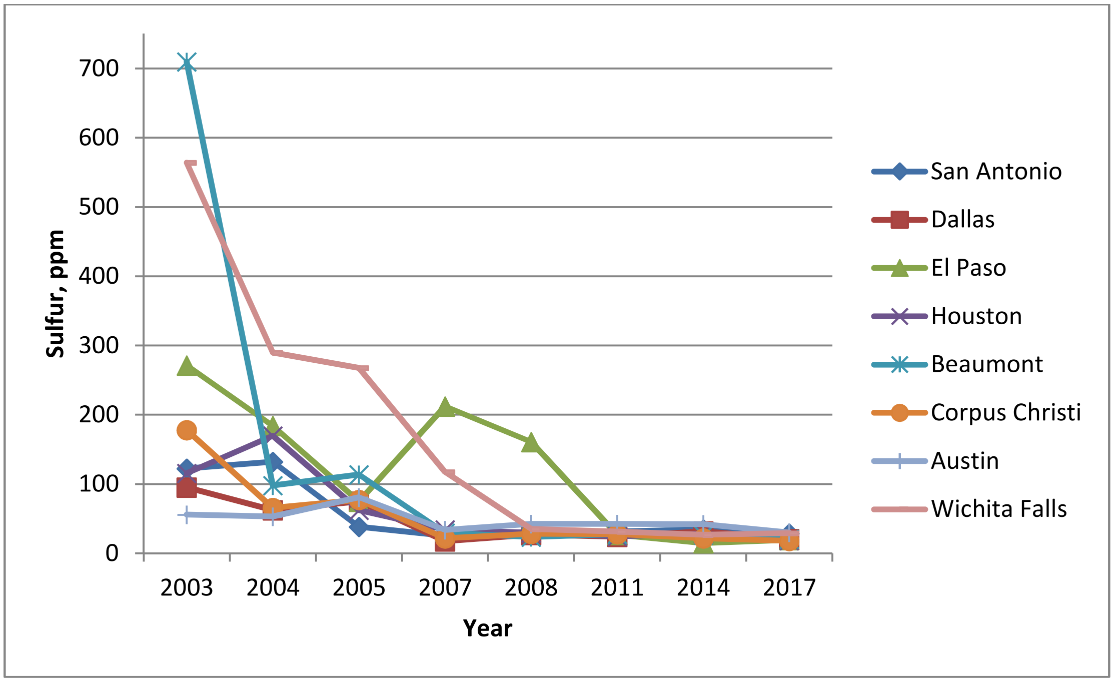


Figure 4. Gasoline Sulfur Trends for Selected Districts (2011-2017)

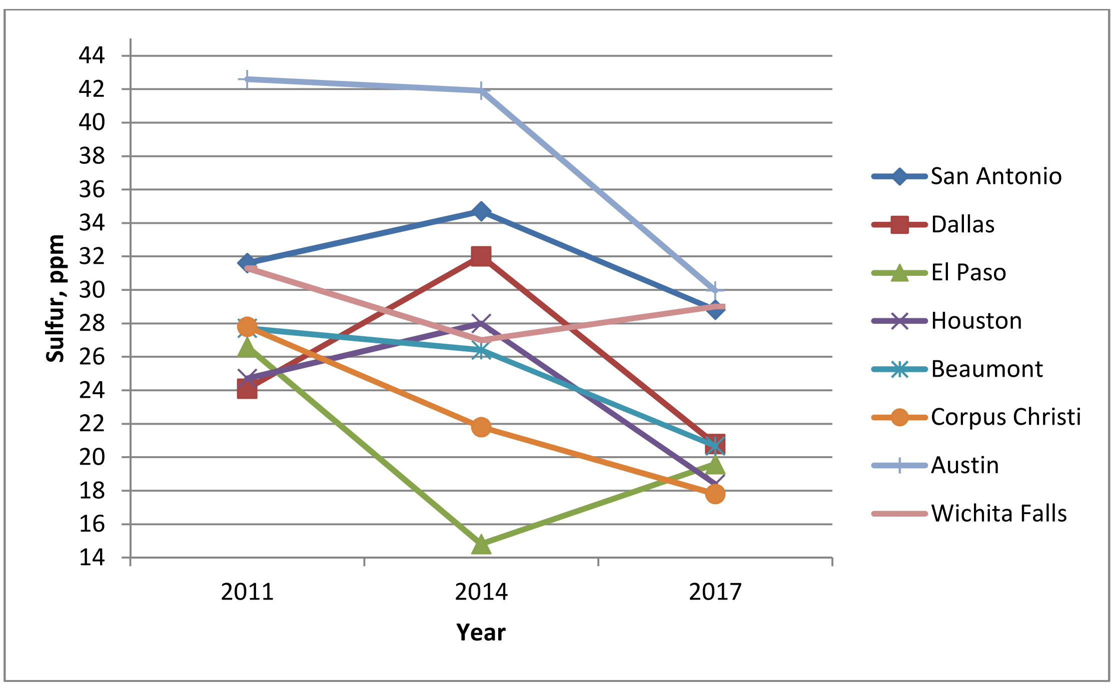


Figure 5. Gasoline Olefins Trends for Selected Districts

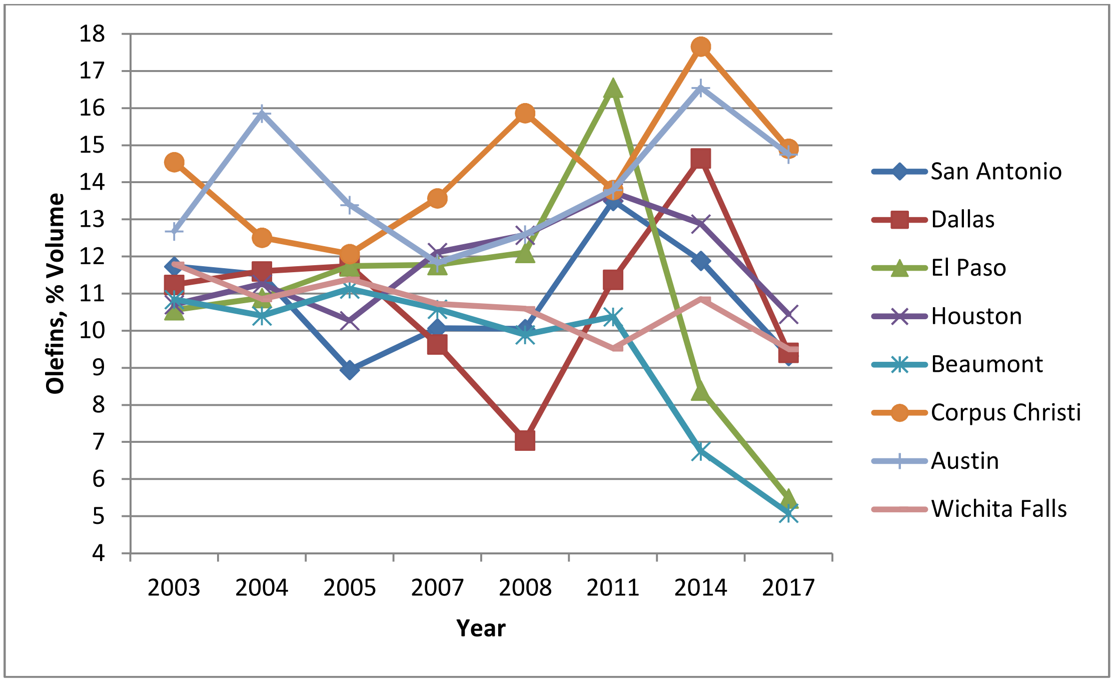


Figure 6. Gasoline Aromatics Trends for Selected Districts

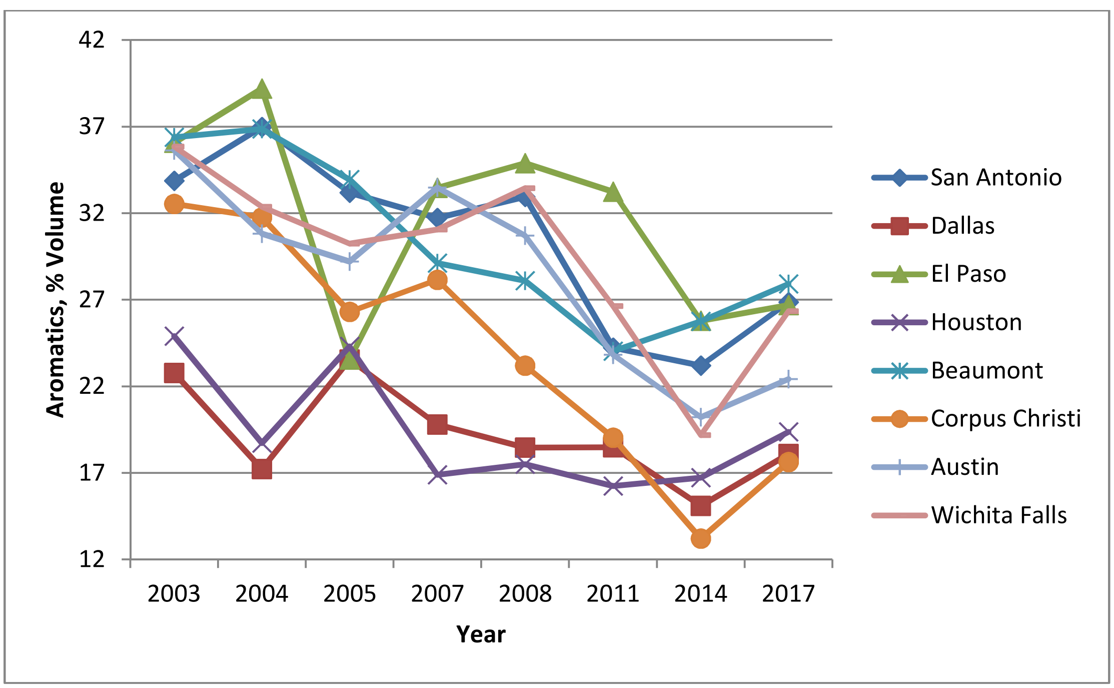


Figure 7. Gasoline Benzene Trends for Selected Districts

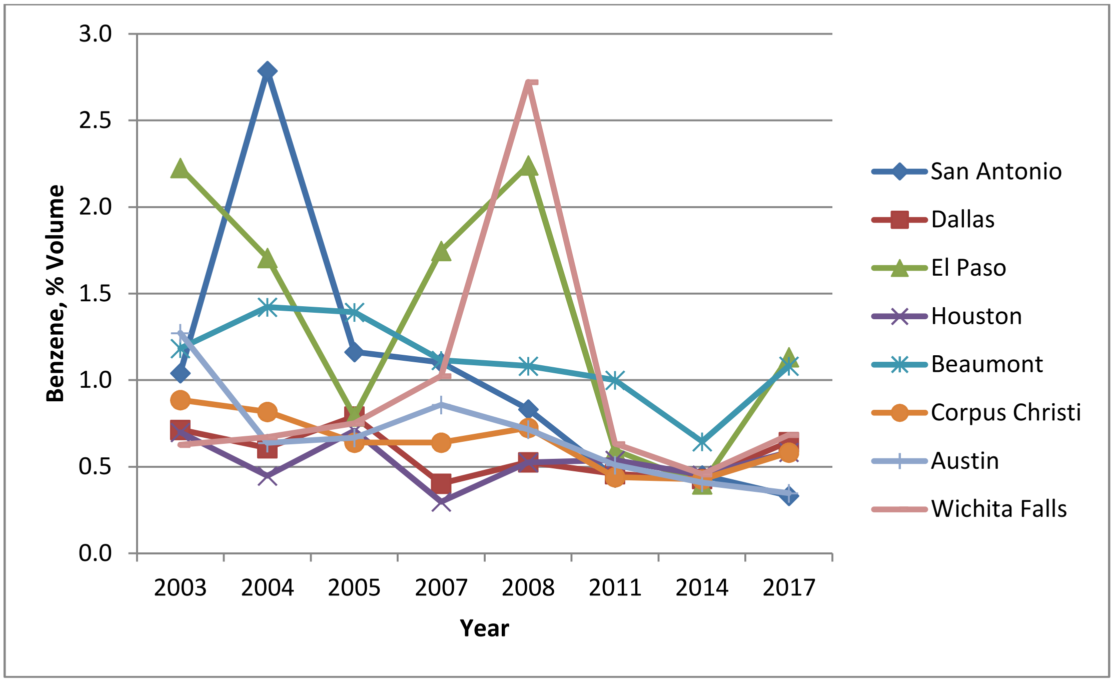


Figure 8. Gasoline MTBE Trends for Selected Districts

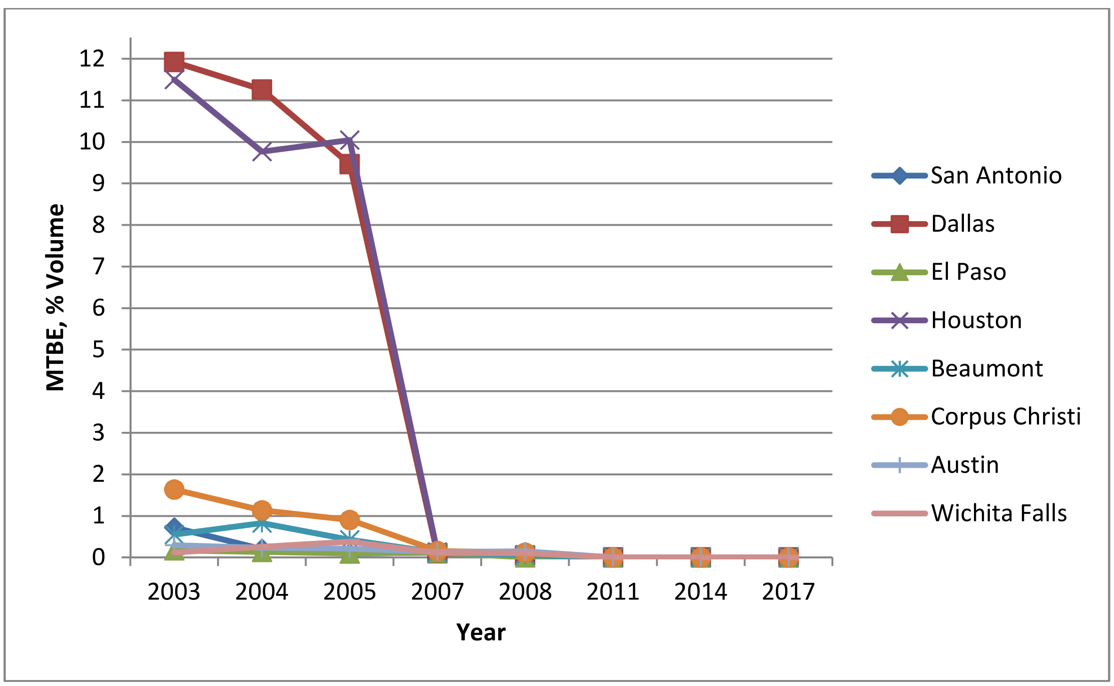


Figure 9. Gasoline ETBE Trends for Selected Districts

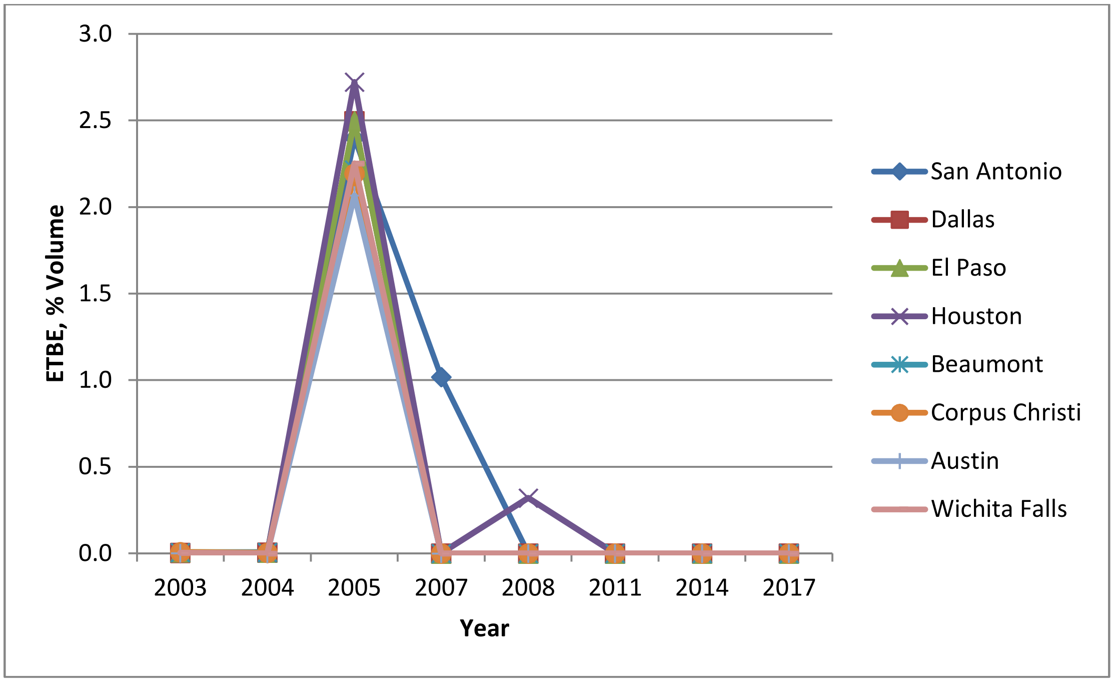


Figure 10. Gasoline Ethanol Trends for Selected Districts

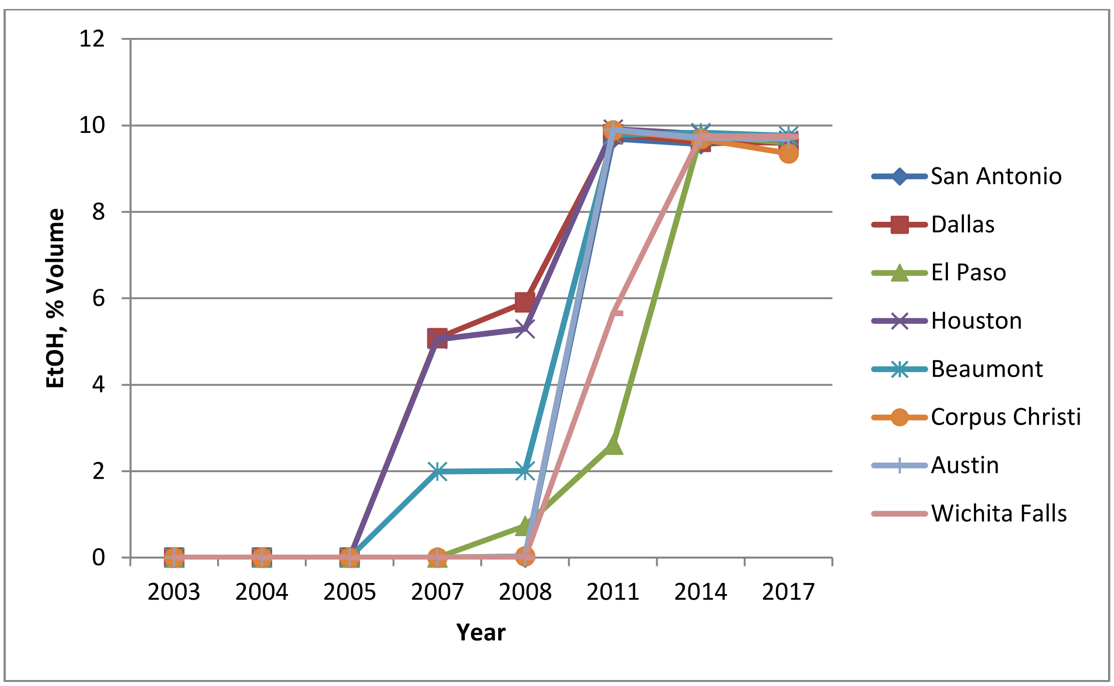


Figure 11. Gasoline TAME Trends for Selected Districts

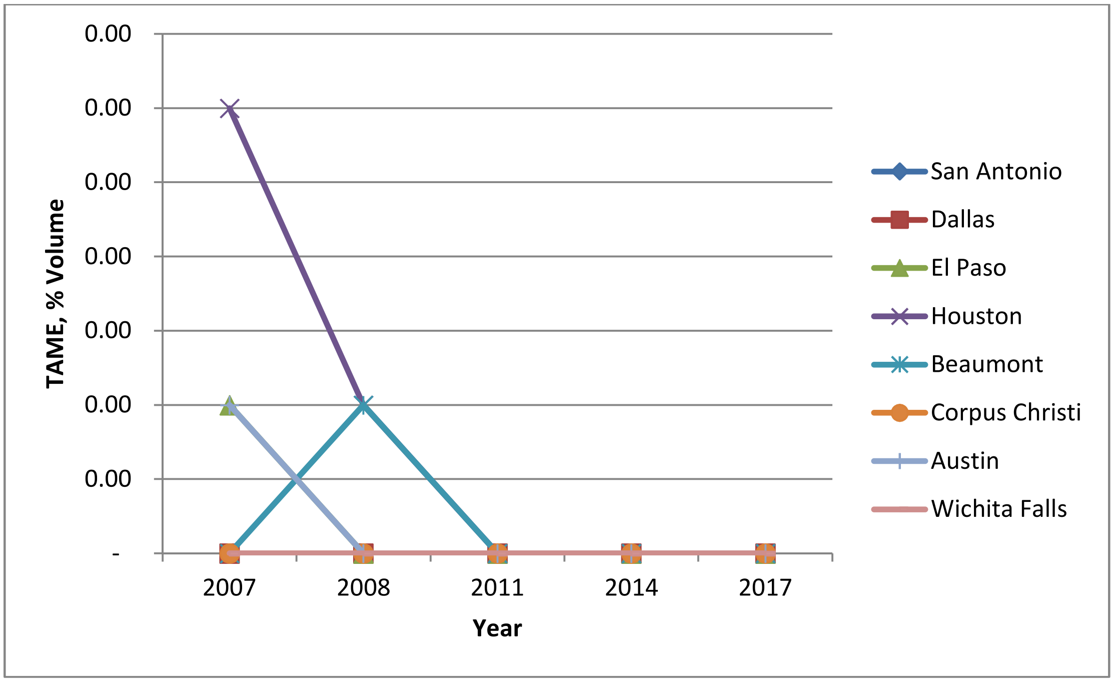


Figure 12. Gasoline E200 Trends for Selected Districts

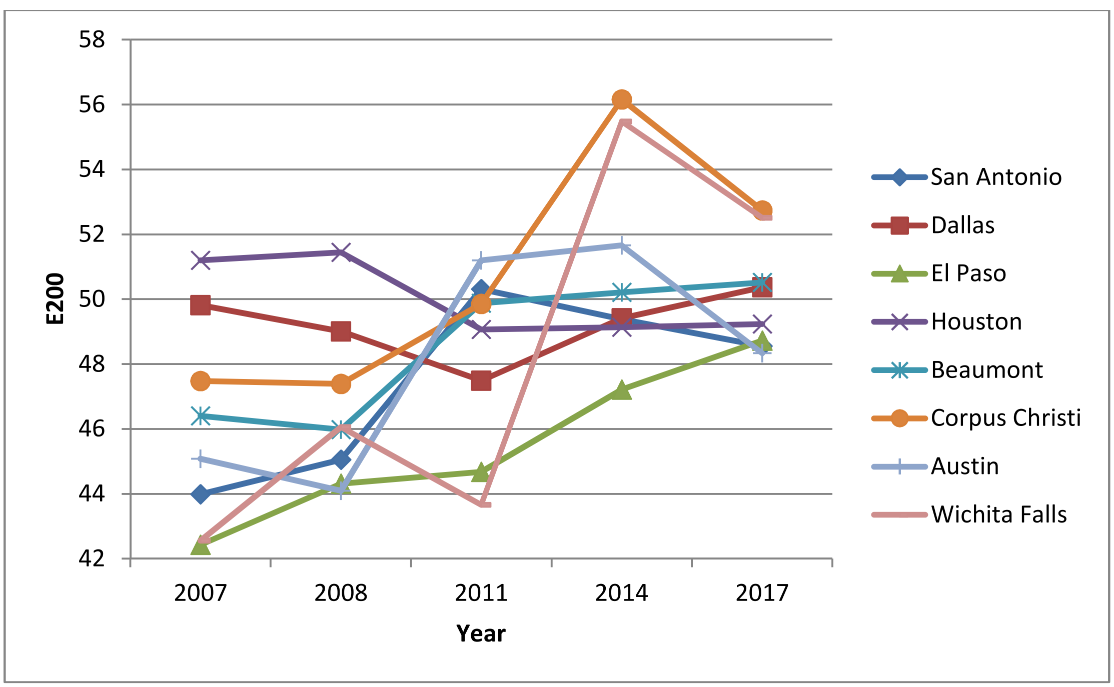
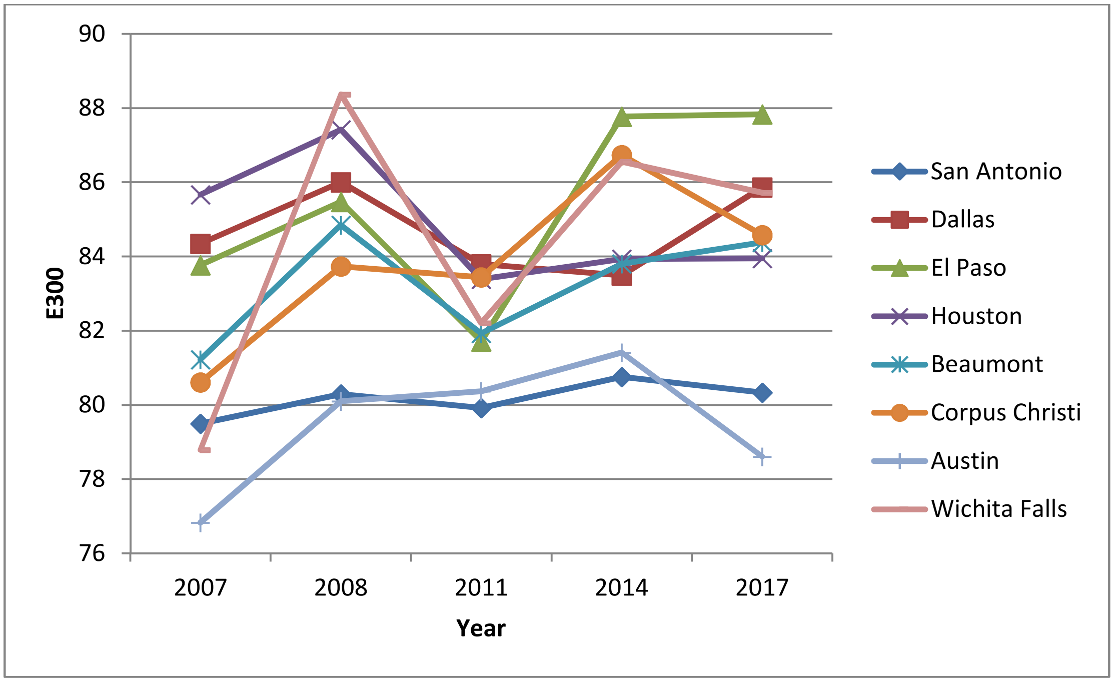


Figure 13. Gasoline E300 Trends for Selected Districts



The following bullets provide some general trend observations regarding the gasoline sampling data:

- RVP in most districts appears to be relatively stable over time. Most values range from 6.5 to just under 8.0, except Wichita Falls district. For Wichita Falls, the RVP values range from a low of 7.78 in 2007 to a high of 9.11 in 2017.
- Sulfur levels have been below 50 ppm since 2011, as expected with the current Federal sulfur fuel standards.
- There doesn't appear to be any obvious trends for olefins in most districts over time. Aromatics display a general downward trend since 2008. Benzene values also represent a downwards trend since 2008 for all districts, except Dallas and Houston.
- Non-ethanol oxygenates (i.e., ETBE, TAME, and MTBE) were only observed in trace amounts, if at all.

Figure 14. Diesel Aromatics Trends for Selected Districts

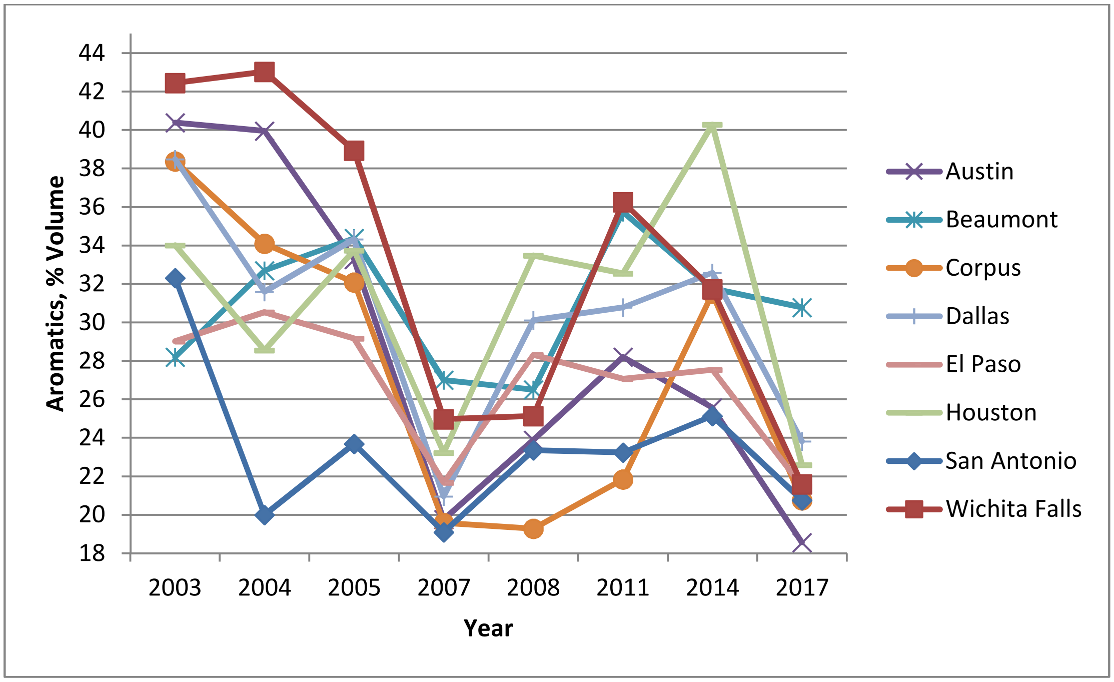


Figure 15. Diesel Olefins Trends for Selected Districts

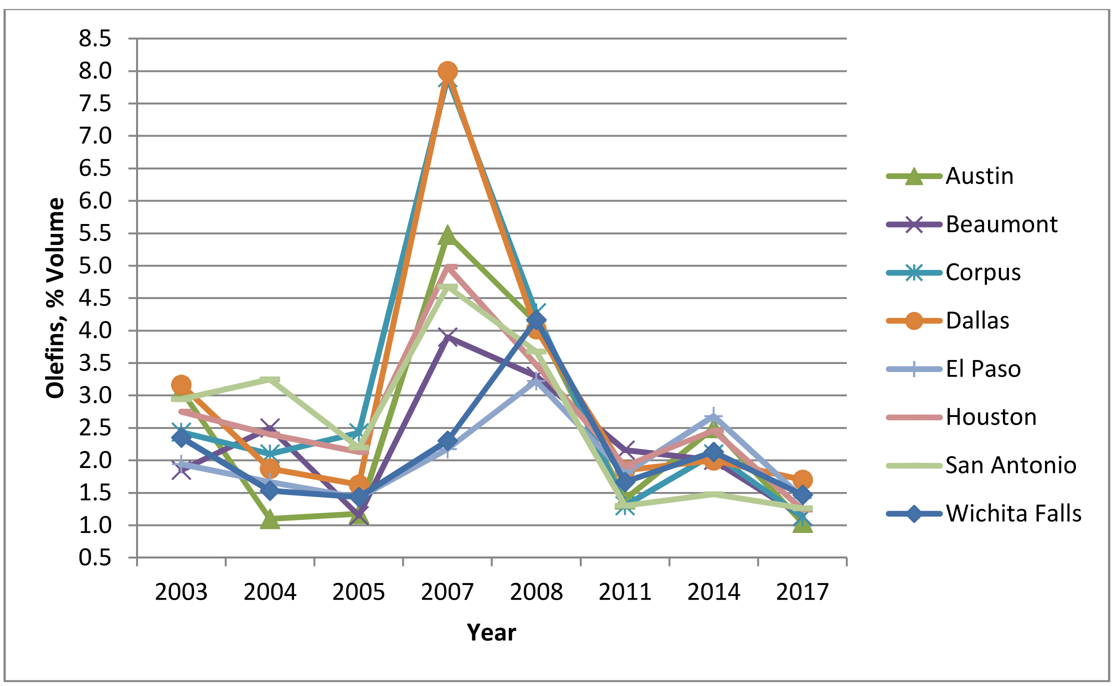


Figure 16. Diesel Saturates Trends for Selected Districts

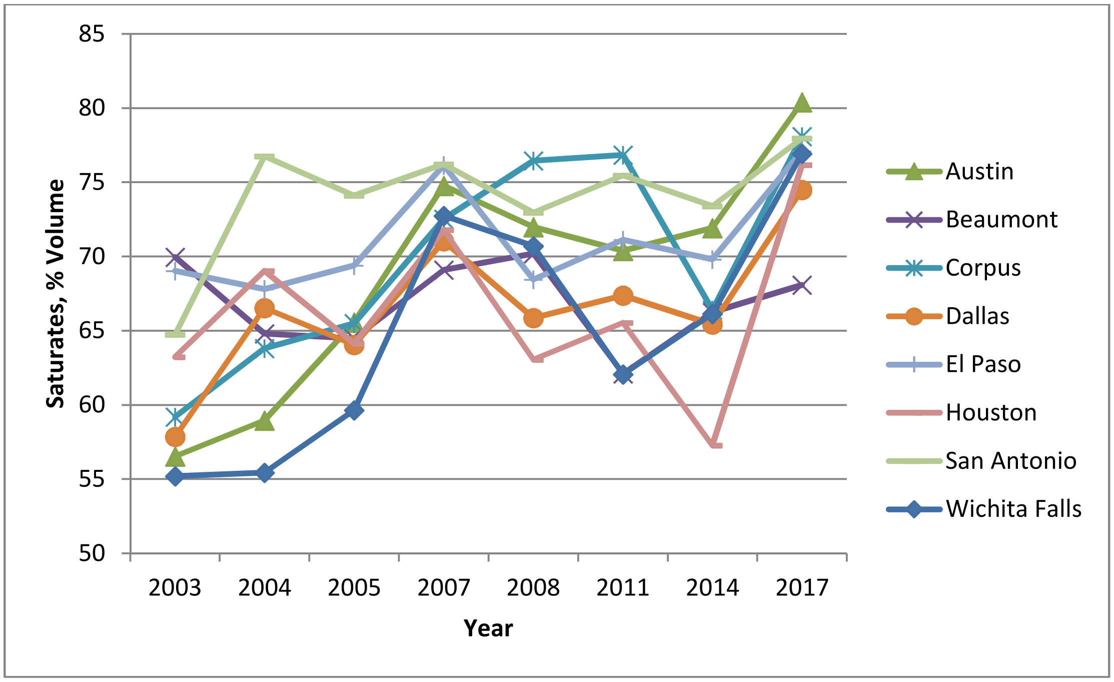


Figure 17. Diesel Sulfur Trends for Selected Districts

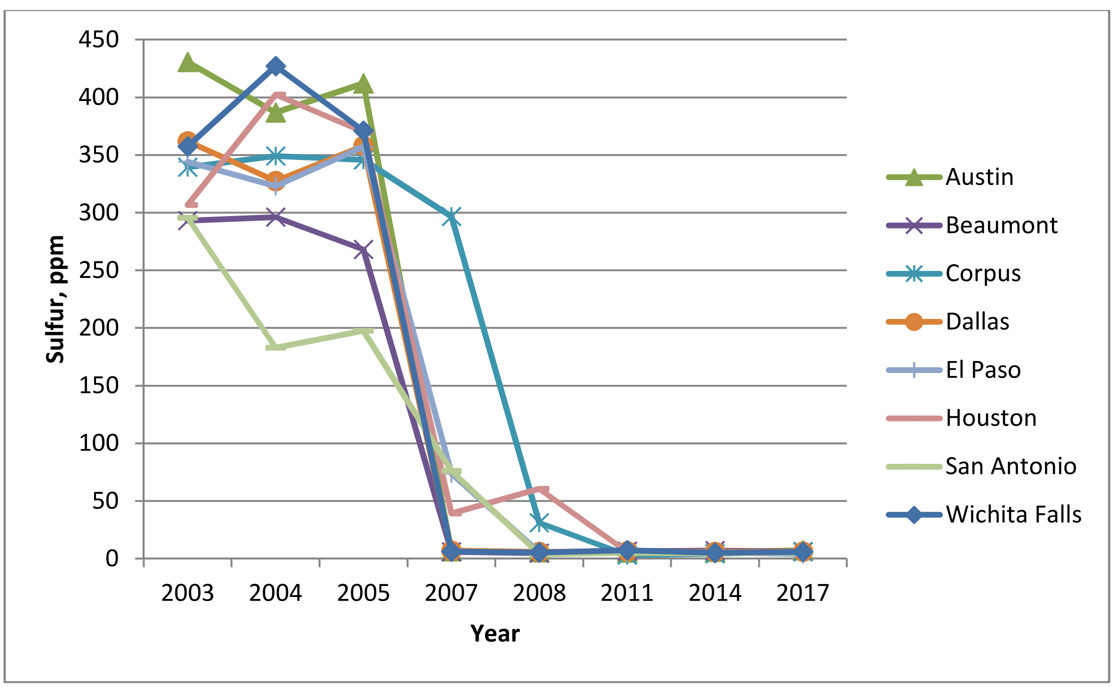


Figure 18. Diesel Sulfur Trends for Selected Districts (2011-2017)

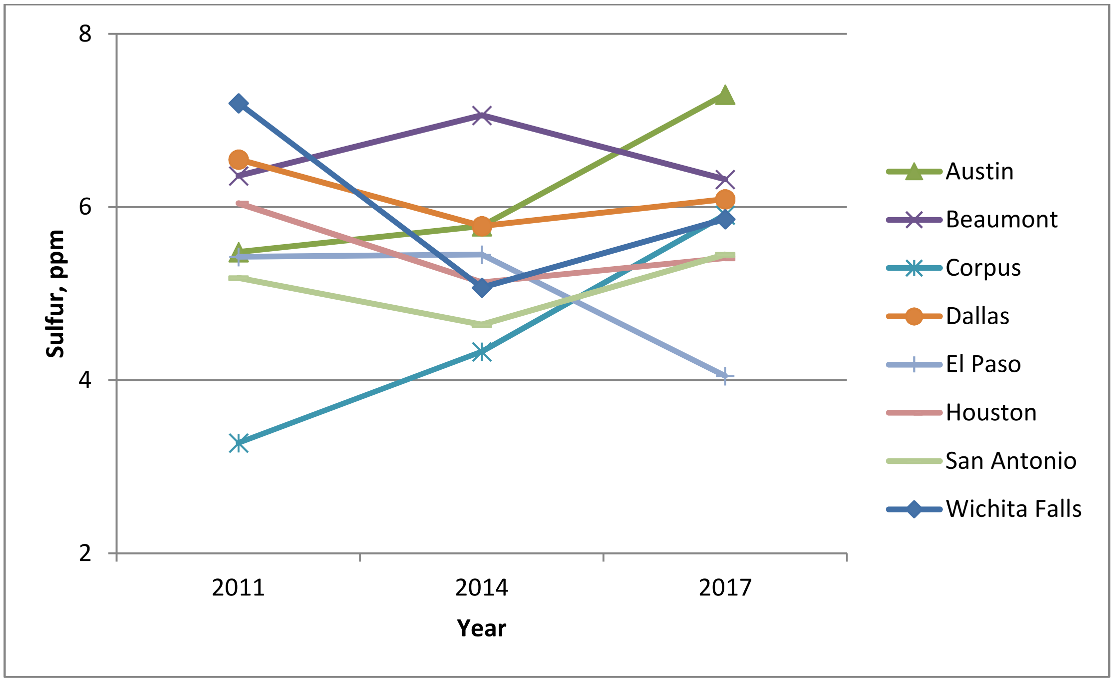


Figure 19. Diesel Cetane Trends for Selected Districts

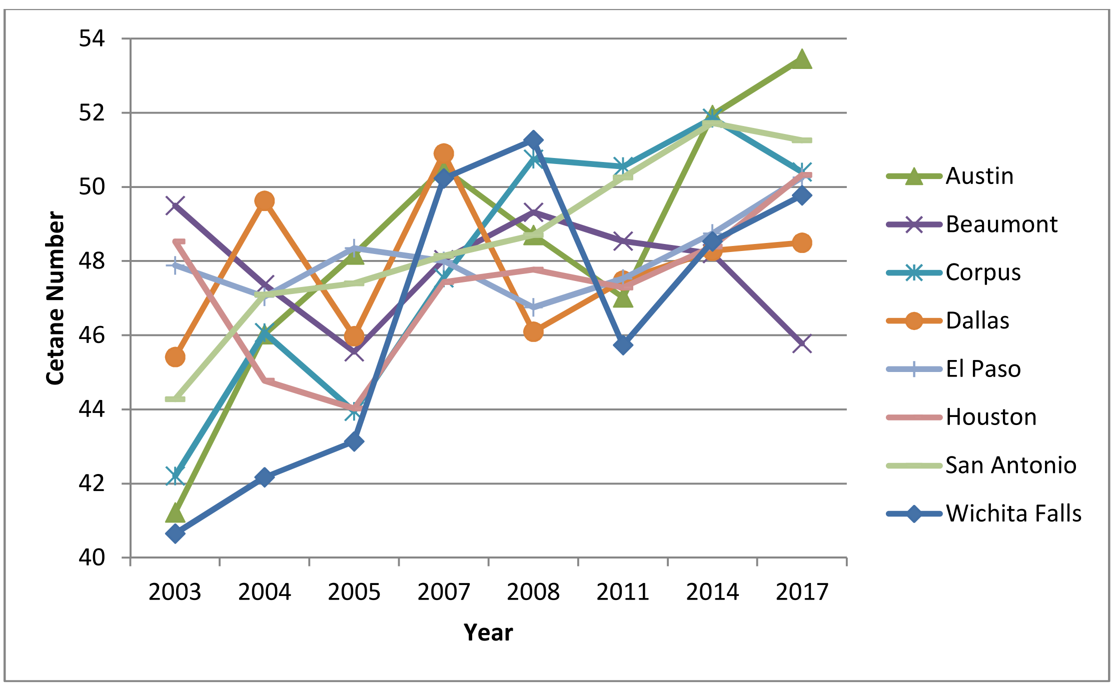


Figure 20. Diesel Sepcific Gravity Trends for Selected Districts

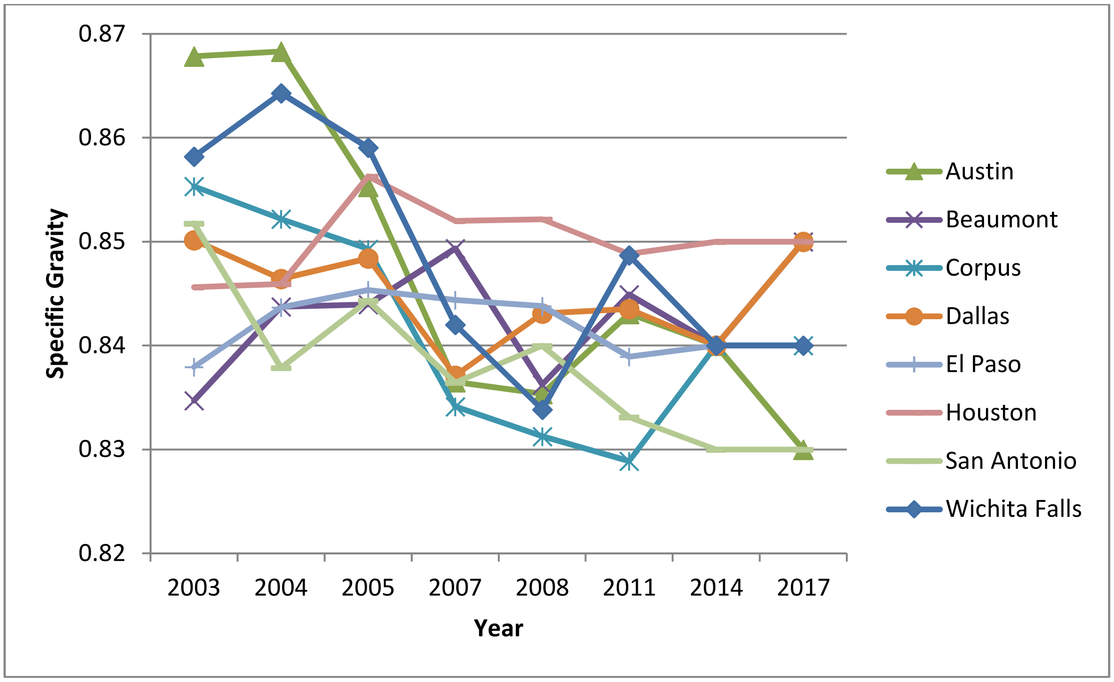
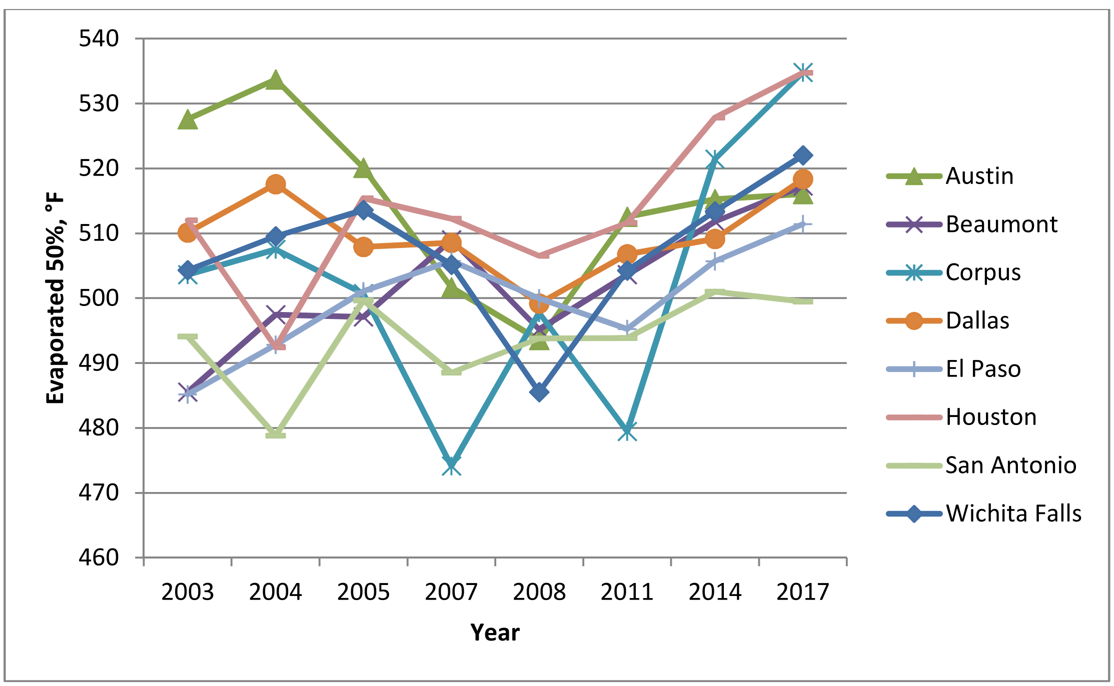


Figure 21. Diesel T50 Trends for Selected Districts



Some general observations about the diesel trends are as follows:

- Aromatics percentage varies between 18% and 43% over time, with the highest values being in 2003. There is a general downward trend from 2003 to 2007. From 2007 till 2014, the aromatics values increased across all districts. The aromatics values for 2017 dropped from the 2014 levels.
- Olefins percentages were at their highest levels during the 2007-2008 period and the trends exhibit a sharp decrease from 2008 to 2017 levels. The saturates on the other hand exhibit an upward trend (i.e., increase in values from 2003 to 2017) with 2017 values being the highest for all districts except Beaumont. For Beaumont, the saturate values peaked in 2008.
- Sulfur content values exhibit a sharp downward trend from 2003 to 2017. All the districts had their peak average sulfur values during the 2003-2005 period. Since 2011, all the districts had average sulfur content value below the 8 ppm level, consistent with the Federal ultra-low sulfur fuel requirments.
- Most districts exhibit a general upward trend for the average cetane number values, with Beaumont being the only exception. For the Beaumont district, the cetane number values have been fairly stable, with 2017 value being lower than the 2014 value.
- For specific gravity values, most districts display a general downward trend from 2003 through 2007, although there is no clear tren thereafter.
- The T50 values for the selected districts are tightly grouped between 499 and 535, with a slight upward trend starting in 2008.

6.0 QUALITY ASSURANCE

ERG performed a review of the lab analysis results for all gasoline and diesel samples, looking for possible outliers or unusual data distributions. ERG evaluated the minimum, maximum, average, and standard deviation for lab testing results, by TxDOT district. The values were then plotted against previous years and other districts to highlight possible outliers. Trend lines also aid in identifying outliers created during post-processing the lab results. One set of trend lines helped to identify erroneous results from a single diesel sample that was collected in the San Antonio district (Sample ID 1740356). These findings were communicated to SwRI. SwRI re-ran the lab analytical tests on the single diesel sample and provided revised results. It was also established that the error was not due to sample contamination.

Prior to ERG receiving the lab test results, SwRI performed rigorous QA/QC checks of both the samples received and the equipment used during testing. These QA/QC procedures are described in detail below.

6.1 Calibrations and Quality Control Checks

6.1.1 Instrument/Equipment Calibration and Frequency

6.1.1.1 Detailed Hydrocarbon Analysis, ASTM 6729-14

The instrument is calibrated by running the calibration standard containing the 400 plus components and verifying their identification using the provided chromatogram.

6.1.1.2 Reid Vapor Pressure, ASTM D 5191-15

All instruments for this test are calibrated by the SwRI Calibration Laboratory every 6 months.

6.1.1.3 Sulfur, ASTM D 2622-16

The x-ray instruments for this test are calibrated annually with drift correction and calibration verification performed daily.

6.1.1.4 Distillation, ASTM D 86-16a

An in-house maintenance group calibrates each distillation rig every three months. Each temperature probe is calibrated every 6 months using 100% toluene.

6.1.1.5 Cetane Number, ASTM D 613-13

The rating units are calibrated daily to the range of each sample.

6.1.1.6 Aromaticity, ASTM D 1319-16e1

The electronic caliper used for rod measurements is calibrated every 6 months. The pressure gauges used in the rod set-ups are calibrated annually. The black lights used in the procedure are also calibrated annually.

6.1.1.7 Sulfur, ASTM D 5453-16e1

Samples will be analyzed using ultraviolet fluorescence. The instrument is calibrated every three months.

6.1.1.8 API Gravity, ASTM D 1298-12b

New calibrated hydrometers are acquired every twelve months to cover the range of gasoline and diesel samples.

6.1.1.9 Flash point, ASTM 93-16

The in-house maintenance group calibrates the temperature probe and stirrer rotation every 12 months.

6.1.1.10 Nitrogen, ASTM D 4629-12

The instruments are calibrated every three months.

6.1.1.11 Polycyclic and Total Aromatic, ASTM 5186-15

The systems performance is set to meet ASTM D 5186-03.

6.1.1.12 Benzene, ASTM D 3606-10e1

Each instrument is calibrated daily using a curve with a series of calibration standards containing benzene from 0 to 5% and toluene from 0.5 to 20%. Every tenth sample and at the end of the tray a QA sample containing benzene and ethanol is run, to ensure instrument stability and performance. Purchased standards are also used for verification. Flow and valve timing is checked on a minimum of once a month and at any other time that non-routine maintenance is performed. Control charts are maintained and monitored daily for process stability for each instrument.

6.1.1.13 Oxygenates, ASTM D 5599-15

Each chromatograph is calibrated with a standard set at regular intervals, and the calibration is verified daily before any sample run. The verification includes measurement of a set of QA/QC standards with internal standards. Several external standards are used which include varied concentrations of TAME, ethanol, and MTBE. A blank and one of the instrument calibration standards containing approximately 0.5% of each component are also included at the beginning of each tray to determine if proper resolution is being achieved on each column. Each sample contains an internal standard to correct for any variation in injection volume.

A QA/QC sample is placed every 10 samples and at the end of each tray. A sample is run in duplicate every 10 samples. Regular instrument maintenance, multiple daily calibration checks, column performance checks and review of the gas chromatograph traces for excessive noise, drift, or other operational problems provide assurance that a system is in place that will generate quality data. Control charts are maintained and monitored daily for process stability for major oxygenate components for each instrument.

6.1.2 Quality Control

6.1.2.1 Detailed Hydrocarbon Analysis, ASTM D 6729-14

The laboratory will routinely monitor the repeatability and reproducibility of its analysis. The repeatability will be monitored through the use of laboratory replicates at the rate of one per batch or at least one per 10 samples whichever is more frequent. Reproducibility will be monitored through the use of a QC sample analyzed at the rate of one per batch or at least one per 15 samples whichever is more frequent.

The range (R) for the duplicate samples should be less than the following limits:

Benzene	0.047*C
MTBE	0.032*C
2,2,4 Trimethyl pentane	0.034*C

Where:
$C = (C_o+C_d)/2$
C_o = Concentration of the original sample
C_d = Concentration of the duplicate sample
R = Range, $| C_o - C_d |$

The QC sample will be plotted on an individual control chart and the Upper and Lower control limits will be determined in accordance with OAE Standard Operating Procedure 4.20 – Revision 5 *Statistical Methods*.

6.1.2.2 Reid Vapor Pressure, ASTM D 5191-15

RVP systems are verified every 20 samples with a QC gasoline sample. The systems are verified with 2,2-dimethylbutane every 6 months. The system is also verified with 2,2 dimethylbutane every 6 months.

6.1.2.3 Sulfur, ASTM D 2622-16

Sulfur is analyzed using the multi-point calibration curves specified in Method D 2622, which are stored in the system computer. At the beginning of each shift the instrument is verified using a purchased QA standard. Drift corrections are applied as needed. Control charts are maintained on the sulfur procedure. This test is included in many regional and ASTM crosscheck programs in which we participate.

6.1.2.4 Distillation, ASTM D 86-16a

Full instrument verification is conducted on each unit on an annual basis and daily system verification is completed prior to running any sample at the start of each day. Control charts are maintained on each instrument and a verified barometer is used for barometric correction of the data. Electronic parts are checked as specified in the lab calibration and recall schedule and at any time that non-routine maintenance is performed. This test is included in many of the regional and ASTM crosscheck programs in which we participate.

6.1.2.5 Cetane Number, ASTM D 613-16e1

The rating units are calibrated daily to the range of each sample.

6.1.2.6 Aromaticity (FIA), ASTM D 1319-15

The FIA results are monitored with a daily QA sample. The current QA material is a surrogate fuel blended to reflect RFG aromatic concentrations. This test is run on a new column every day in the same manner as the sample testing is performed. Each analyzer column is checked for internal and external dimensions, and silica gel parameters are monitored as per the ASTM procedure.

6.1.2.7 Sulfur, ASTM D 5453-16e1

The instrument is monitored daily by running a quality control sample with known sulfur content. Control charts are maintained on each instrument. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

6.1.2.8 Flash Point, ASTM D 93-16

The flash point results are monitored through daily verification with an anisole reference material and an annual verification using an Accu Standard ASTM-P-133-01 certified reference material. The instrument undergoes an annual instrument calibration by internal calibration team.

6.1.2.9 Nitrogen, ASTM D 4629-12

The Antek instruments are monitored daily by running a quality control sample with known nitrogen content. Control charts are maintained on each instrument. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

6.1.2.10 Polycyclic and Total Aromatics, ASTM D 5186-15

The Selerity Technology instrument is monitored daily by running a quality control sample with known aromatic content. Control charts are maintained for the instrument. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

6.1.2.11 Benzene, ASTM D 3606-10e1

Each instrument is calibrated as needed using a curve with a series of calibration standards containing benzene from 0 to 5% and toluene from 0.5 to 20%. Every tenth sample and at the end of the tray a QA sample containing benzene and ethanol is run, to ensure instrument stability and performance. Control charts are maintained for each instrument. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

6.1.2.12 Oxygenate, ASTM D 5599-15

Each chromatograph is calibrated with a standard set at regular intervals, and the calibration is verified daily before any sample run. The verification includes measurement of a set of QA/QC standards with internal standards. Several external standards are used which include varied concentrations of TAME, ethanol, and MTBE. A blank and one of the instrument calibration standards containing approximately 0.5% of each component are also included at the beginning of each tray to determine if proper resolution is being achieved on each column. Each sample contains an internal standard to correct for any variation in injection volume. Control charts are maintained for each instrument. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

A QA/QC sample is placed every 10 samples and at the end of each tray. A QA sample is run in duplicate every 10 samples. Regular instrument maintenance, multiple daily calibration checks, column performance checks and review of the gas chromatograph traces for excessive noise, drift, or other operational problems provide assurance that a system is in place that will generate quality data. Control charts are maintained and monitored daily for process stability for major oxygenate components for each instrument.

6.2 Calibrations and Quality Control Acceptance Criteria

The SwRI laboratory staff conducted the initial Data verification. They accepted or rejected the data based upon the QC samples and, if applicable, chromatography and laboratory replicates.

The SwRI Program Manager reviewed the data. The data was reviewed for apparent accuracy, completeness and reasonableness. The SwRI Program Manager decided whether to validate, rerun or invalidate the data, based on their review.

A Corrective Action Report (CAR) was issued to document the investigation into any discrepancies noted during the technical assessments. The CAR will be issued in accordance with OAE Standard Operating Procedure 4.13 – Revision 5 Nonconformance, Preventive and Corrective Action, Customer Complaints.

6.2.1 Detailed Hydrocarbon Analysis, ASTM D 6729-14

Since typical gasoline is a mixture of over 400 components, it would be impractical if not impossible to impose data quality indicators on each analyte of interest. Therefore, one component from each of the functional groups will be tracked to assess the overall quality of the analytical performance.

Table 7. Data Quality Indicators – Detailed Hydrocarbon Analysis (ASTM D 6729-14)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term)	The difference between replicate results, in the normal and correct operation of the method, should not exceed the following values expressed as percentages of the average of the two values: 4.7 % Benzene 3.2 % MTBE 3.4 % 2,2,4 Trimethyl pentane
Bias	The bias of this test method cannot be determined since an appropriate standard reference material is not available. It is impossible to account for every potential co-elution and quantify the magnitude of the interference.	N/A
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Since a suitable reference material is not available, Accuracy will be maintained by a QC sample.	The 95 CI limits for the QC sample should be as follows expressed as percentages of the average of the two values: 9.9 % Benzene 8.9 % MTBE 9.5 % 2,2,4 Trimethyl pentane
Representative	Fuel samples will be collected by field contractors at locations defined by ERG.	N/A
Comparability	The resulting data set is defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions if the measurement technique. And in the case of petroleum chemistry are generally not quantifiable. The data set should give a reasonable estimate of the component distribution in the fuel supply but it may not be directly comparable to other methods.	N/A

Table 7. Data Quality Indicators – Detailed Hydrocarbon Analysis (ASTM D 6729-14)

DQI	Definition/Discussion	Measurement Performance Criteria
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%
Sensitivity	Upper and lower concentration limits are defined in table A1.2 of ASTM D 6729. For a list of predominate compounds and identified co-eluting compounds see table 4 of ASTM D 6729.	See ASTM D 6729 -14

6.2.2 Reid Vapor Pressure, D 5191-15

Table 8. Data Quality Indicators – RVP (ASTM D 5191-15)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term)	See ASTM D 5191-15
Bias	There is no accepted reference material suitable for determining the bias for the procedures in this test method. Bias cannot be determined.	N/A
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample.	See ASTM D 5191-15
Representative	Fuel samples will be collected by field contractors at locations defined by ERG.	N/A
Comparability	The resulting data is defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique.	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%
Sensitivity	Upper and lower vapor pressure limits are defined in table 1.1 of ASTM D 5191-15	See ASTM D 5191-15

6.2.3 Sulfur, ASTM D2622-10

Table 9. Data Quality Indicators – Sulfur (ASTM D 2622-16)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term)	See ASTM D 2622-16.
Bias	Sulfur bias is detailed in D 2622-16.	See ASTM D 2622-16

Table 9. Data Quality Indicators – Sulfur (ASTM D 2622-16)

DQI	Definition/Discussion	Measurement Performance Criteria
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample.	See ASTM D 2622-16.
Representative	Fuel samples will be collected by field contractors at locations defined by ERG.	N/A
Comparability	N/A	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%
Sensitivity	Test method covers the determination of total sulfur in gasoline and diesel fuel.	See ASTM D 2622-16.

6.2.4 Distillation, ASTM D 86-16a

Table 10. Data Quality Indicators – Distillation (ASTM D 86-16a)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term)	See ASTM D 86-16a.
Bias	Due to the use of total temperature probes, the distillation temperatures in this test method are somewhat lower than the true temperatures. The amount of bias depends on the product being distilled and the thermometer used. The bias due to the emergent stem has been determined for toluene and is shown in ASTM D 86-16a.	N/A
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample.	See ASTM D 86-16a
Representative	Fuel samples will be collected by field contractors at locations defined by ERG.	N/A
Comparability	The resulting data is defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique.	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%
Sensitivity	The method is designed for the analysis of distillate fuels; it is not applicable to products containing appreciable quantities of residual material.	See ASTM D 86-16a

6.2.5 Cetane Number, ASTM D 613-16e1

Table 11. Data Quality Indicators – Cetane Number (ASTM D 613-16e1)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term)	See ASTM D 613-16e1.
Bias	The procedure in this test method for cetane number of diesel fuel oil has no bias because the value of cetane number can be defined only in terms of the test method.	N/A
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample.	See ASTM D 613-16e1.
Representative	Fuel samples will be collected by field contractors at locations defined by ERG.	N/A
Comparability	The resulting data is defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique.	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%
Sensitivity	The cetane number scale range from zero to 100 but typical testing is in the range of 30 to 65 cetane number.	See ASTM D 613-16e1.

6.2.6 Aromatics and Olefins, ASTM D 1319-15

Table 12. Data Quality Indicators – Aromatics and Olefins (ASTM D 1319-15)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term)	See ASTM D 1319-15.
Bias	Bias cannot be determined because there are no acceptable reference materials suitable for determining the bias for the procedure in this test method.	See ASTM D 1319-15.
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample.	See ASTM D 1319-15.
Representative	Fuel samples will be collected by field contractors at locations defined by ERG.	N/A
Comparability	The resulting data is defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique.	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%

Table 12. Data Quality Indicators – Aromatics and Olefins (ASTM D 1319-15)

DQI	Definition/Discussion	Measurement Performance Criteria
Sensitivity	This test method covers the determination of hydrocarbon types over the concentration ranges from 5 to 99 volume % aromatics, 0.3 to 55 volume % olefins, and 1 to 95 volume % saturates in petroleum fraction that distill below 315 C.	See ASTM D 1319-15.

6.2.7 Sulfur, ASTM D 5453-16e1

Table 13. Data Quality Indicators – Sulfur (ASTM D 5453-16e1)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability.	See ASTM D 5453-16e1.
Bias	Bias study is documented in ASTM Research Report RR-D02-1307 (1992). The report indicated that the bias is within repeatability of the test method.	See ASTM D 5453-16e1.
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample.	See ASTM D 5453-16e1.
Representative	Fuel samples are to be collected by field contractors at locations defined by ERG.	N/A
Comparability	The resulting data is defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique.	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%
Sensitivity	This method covers the determination of total sulfur in liquid hydrocarbons, boiling in the range of 25 to 400 °C with viscosities of 0.2 and 20 cSt at room temperature.	See ASTM D 5453-16e1.

6.2.8 Flash Point, ASTM D 93-16

Table 14. Data Quality Indicators – Flash point, (ASTM D 93-16)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability.	See ASTM D 93-16.

Table 14. Data Quality Indicators – Flash point, (ASTM D 93-16)

DQI	Definition/Discussion	Measurement Performance Criteria
Bias	There is no accepted reference material suitable for determining the bias for the procedure in these test methods, bias has not been determined.	N/A
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term).	See ASTM D 93-16.
Representative	Fuel samples are to be collected by field contractors at locations defined by ERG.	N/A
Comparability	The resulting data is defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique.	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%
Sensitivity	This test method covers the determination of flash point of petroleum products in the temperature range 40 to 360 °C by manual Pensky-Martens closed cup apparatus or an automated Pensky-Marten closed cup apparatus.	See ASTM D 93-16.

6.2.9 Nitrogen, ASTM D 4629-12

Table 15. Data Quality Indicators – Nitrogen, (ASTM D 4629-12)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability.	See ASTM D 4629-12.
Bias	The bias cannot be determined since an appropriate standard reference material containing a known trace level of nitrogen in a liquid petroleum hydrocarbon is not available to form the basis of a bias study.	N/A
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term).	See ASTM D 4629-12.
Representative	Fuel samples are to be collected by field contractors at locations defined by ERG.	N/A
Comparability	The resulting data is defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique.	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%

Table 15. Data Quality Indicators – Nitrogen, (ASTM D 4629-12)

DQI	Definition/Discussion	Measurement Performance Criteria
Sensitivity	This test method covers the determination of the trace total nitrogen naturally found in liquid hydrocarbons boiling in the range of 50 to 400 °C with viscosities between 0.2 and 10 cSt at room temperature.	See ASTM D 4629-12.

6.2.10 Polycyclic and Total Aromatics, ASTM D 5186-15

Table 16. Data Quality Indicators – Polycyclic and Total Aromatics, (ASTM D 5186-15)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability.	See ASTM D 5186-0315
Bias	Reference materials for this test method are in development through ASTM. The bias cannot be determined at this time.	N/A
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term).	See ASTM 5186-15
Representative	Fuel samples are to be collected by field contractors at locations defined by ERG.	N/A
Comparability	The resulting data is defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique.	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%
Sensitivity	This test method covers the determination of the total amounts of monoaromatic and polynuclear aromatic hydrocarbon compounds in motor diesel fuel by SFC. The range of aromatics concentration to which this test method is applicable is from 1 to 75 mass %. The range of polynuclear aromatic hydrocarbon concentrations to which this test method is applicable is from 0.5 to 50 mass %.	See ASTM 5186-15

6.2.11 Benzene, ASTM 3606-10e1

Table 17. Data Quality Indicators – Benzene (ASTM D 3606-10)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term)	See ASTM D 3606-10e1.
Bias	Benzene bias is detailed in D 3606-06e1.	See ASTM D 3606-10e1
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample.	See ASTM D 3606-10e1.
Representative	Fuel samples are to be collected by field contractors at locations defined by ERG.	N/A
Comparability	N/A	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%
Sensitivity	Benzene can be determined between the levels of 0.1 and 5 volume %	See ASTM D 3606-10e1.

6.2.12 Oxygenates, ASTM D 5599-15

Table 18. Data Quality Indicators – Oxygenates, (ASTM D 5599-15)

DQI	Definition/Discussion	Measurement Performance Criteria
Precision	Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term)	See ASTM D 5599-15
Bias	Oxygenate bias is detailed in D 5599.	See ASTM D 5599-15.
Accuracy	Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample.	See ASTM D 5599-15.
Representative	Fuel samples are to be collected by field contractors at locations defined by ERG.	N/A
Comparability	N/A	N/A
Completeness	All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample.	100%
Sensitivity	Test method covers a gas chromatographic procedure for the quantitative determination of organic oxygenated compounds in gasoline having a boiling point limit of 220°C and oxygenates having a boiling point limit of 130°C. It is applicable when oxygenates are present in the 0.1 to 20% by mass range.	See ASTM D 5599-15

6.3 Data Auditing

SwRI reviewed the sample collection receipts for all samples collected to ensure the proper grade was acquired and samples were obtained from designated retail outlets. SwRI also audited the steps of analysis for 30 of the samples taken (> 10%), as required by Category III projects. No data outliers/errors were identified during the audit.

7.0 REFERENCES

ERG, 2014. “2014 Summer Fuel Field Study”, Final report prepared for Texas Commission on Environmental Quality (TCEQ) by Eastern Research Group, Inc. (ERG). August 31, 2014.

EIA, 2017. "Refiners'/Gas Plant Operators' Monthly Petroleum Product Sales Report." Form EIA-782A, Release Date: 8/1/2017. Accessed on 8/9/2017. Internet address: https://www.eia.gov/dnav/pet/pet_cons_refmg_d_STX_VTR_mgalpd_a.htm.

Regan, 2017. TCEQ Petroleum Storage Tank (PST) data provided via email by Michael Regan (TCEQ), February 21, 2017.

ATTACHMENT 1:

Final Sampling Station List,
Includes Alternate Sampling List – provided electronically

ATTACHMENT 2:

SwRI Testing Results for Gasoline – provided electronically

ATTACHMENT 3:

SwRI Testing Results for Diesel – provided electronically

ATTACHMENT 4a:

Updated Fuel Parameter Files for MOVES and TexN – provided electronically

ATTACHMENT 4b:

Gasoline and Diesel Analysis Data and Results – provided electronically

ATTACHMENT 5a:

Round 2 Sampling Test Results, Round 1 vs. Round 2 Analysis Data and Results – provided electronically

ATTACHMENT 5b:

Trends Analysis Data and Results – provided electronically